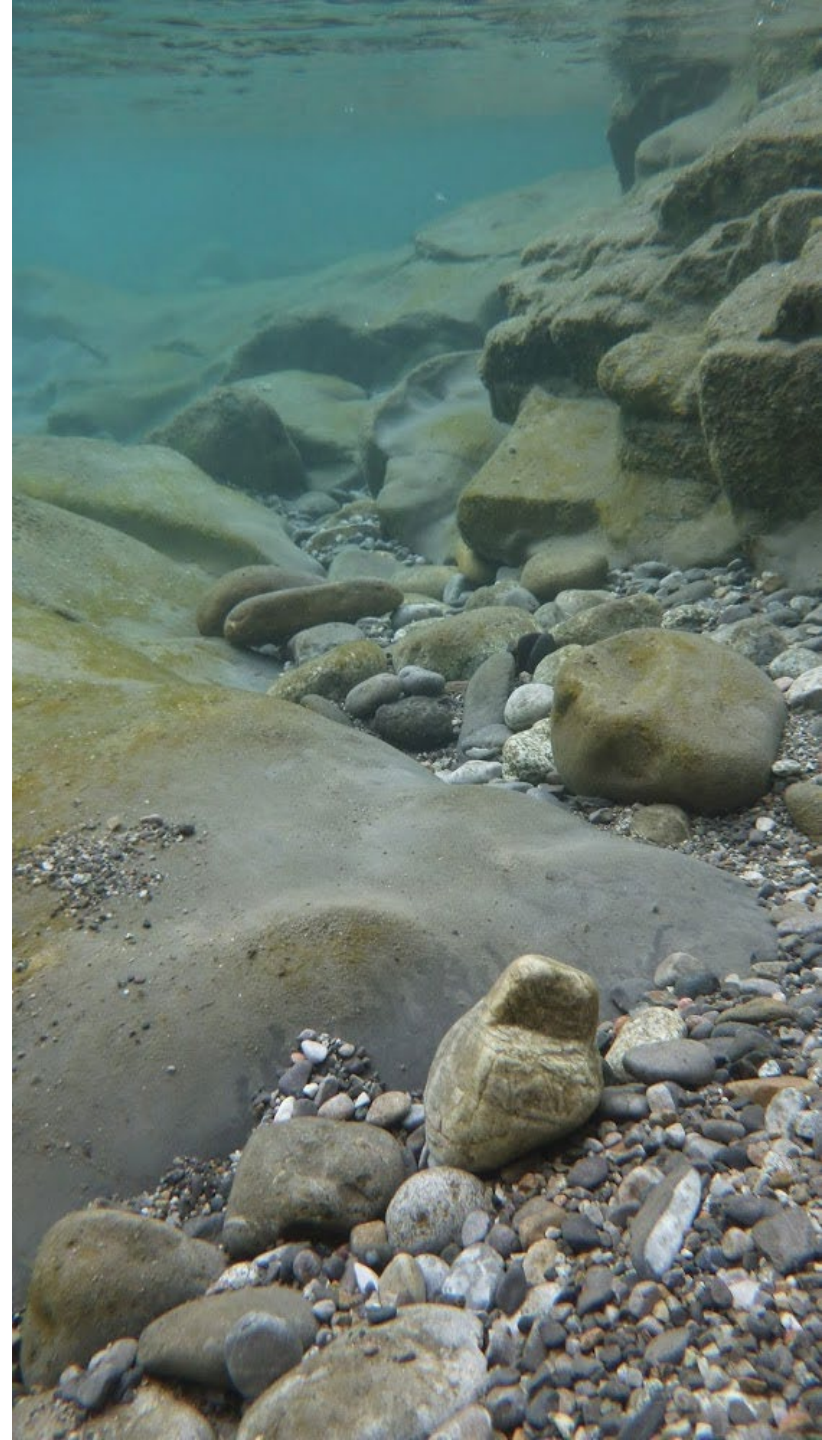


Instream Geomorphic Units

- I. Intro → Geomorphic Units & Process-Form Associations
- II. Classification & Field Identification
- III. Your Book (River Styles)**
 - I. Sculpted, Erosional Bedrock & Boulder GUs
 - II. Mid-Channel, Depositional GUs
 - III. Bank-Attached, Depositional GUs
 - IV. Sculpted, Erosional Fine-Grained GUs
 - V. Unit & Compound GUs
 - VI. Forced GUs
- IV. Continuum of GUs
- V. Fluvial Taxonomy GUs (Topographically Defined)
 - I. Tier 1 – Stage
 - II. Tier 2 – Shape / Form
 - III. Tier 3 – Attributed
- VI. GUT (Geomorphic Unit Toolkit)

Process-Form Associations of Instream GUs

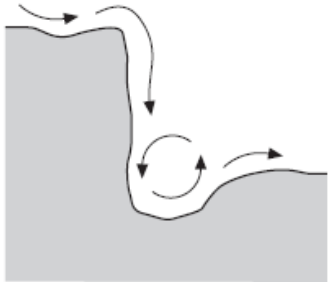
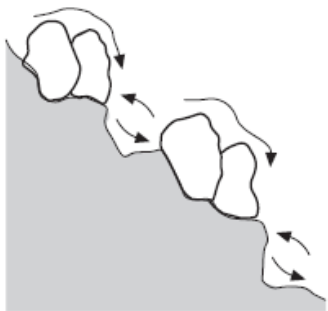
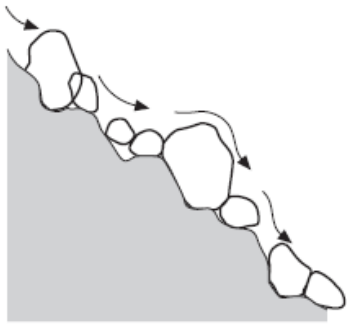
- Four categories differentiated:
 1. Sculpted, erosional bedrock and boulder units
 2. Mid-channel, depositional units
 3. Bank-attached, depositional units
 4. Sculpted, erosional fine-grained units



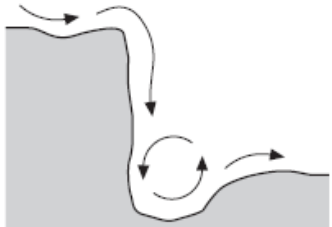
Instream Geomorphic Units

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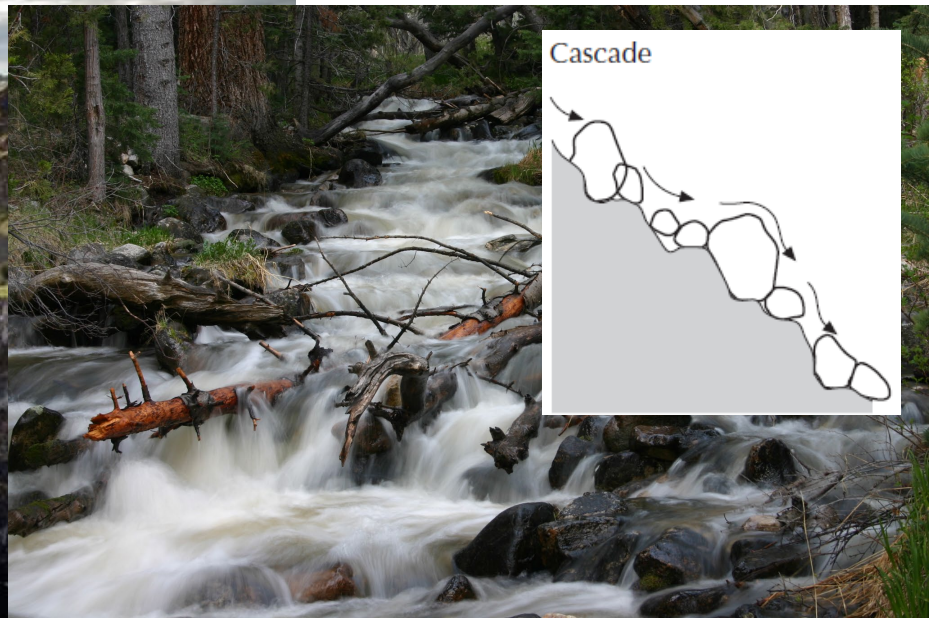
Table 8.1 Sculpted, erosional geomorphic units^a

Unit	Form	Process interpretation
Bedrock step (waterfall) 	Locally resistant bedrock that forms channel-wide drops. Transverse waterfalls >1 m high separate a backwater pool from a plunge pool downstream.	Erosional features formed and maintained as highly turbulent flow falls near-vertically over the lip of the step. Steps are major elements of energy dissipation. These locally resistant areas may represent headward-migrating knickpoints. Equivalent features may be forced by wood.
Step-pool 	Formed on steep slopes ($0.03\text{--}0.10\text{ m m}^{-1}$) channel-spanning stair-like features comprise bedrock, or boulder and cobble clasts or wood separated by areas of quieter flow in a <i>plunge pool</i> downstream. The risers of individual steps are generally made up of several large boulders, or keystones.	A cyclic pattern of acceleration and deceleration characterises the flow regime as water flows over or through the boulders forming each step before plunging into the pool below. Such tumbling flow is supercritical over the step and subcritical in the pool. Turbulent mixing results in considerable energy dissipation. Step development is strongly influenced by local sediment supply (availability of keystones) and transport conditions.
Cascade 	Very stable, coarse-grained or bedrock features observed in steep, bedrock-confined settings. Comprise longitudinally and laterally disorganised bed material, typically cobbles and boulders. Flow cascades over large boulders in a series of short steps about one clast diameter high, separated by areas of more tranquil flow of less than one channel width in extent.	More than 50% of the stream area is characterised by supercritical flow. Typically associated with downstream convergence of flow. Near-continuous tumbling/turbulent and jet-and-wake flow over and around large clasts contributes to energy dissipation. Finer gravels can be stored behind larger materials or wood. During moderate flow events, finer bedload materials are transported over the more stable clasts that remain immobile. Local reworking may occur in high-magnitude, low-frequency events.

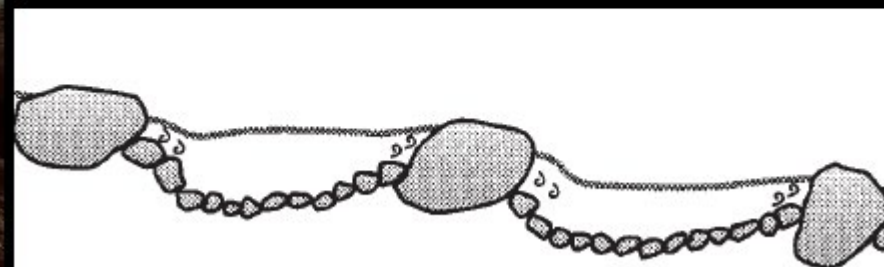
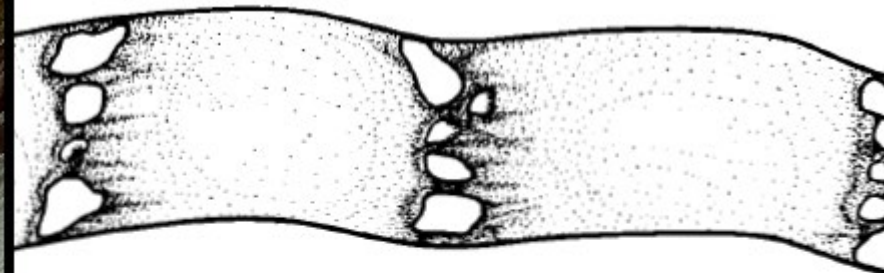
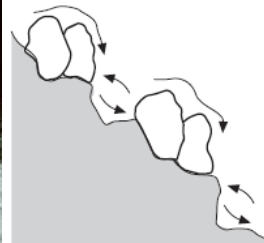
Bedrock step
(waterfall)



Cascade




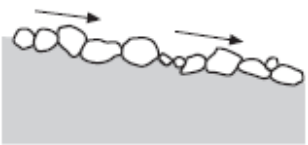

Step-pool





© ET-AL USU : <http://etal.joewheaton.org>

Table 8.1 (Continued)

Unit	Form	Process interpretation
<p>Rapid</p> 	<p>Very stable, steep, ridge-like sequences formed by arrangements of boulders in irregular transverse ribs that partially or fully span the channel in bedrock-confined settings. Rapids in bedrock channels may be analogous with riffles in alluvial systems. Individual particles break the water surface at low flow stage.</p>	<p>Boulders are structurally realigned during high-energy events to form stable transverse ribs that are not associated with either divergent or convergent flow. Typically, 15–50% of the stream demonstrates supercritical flow.</p>
<p>Run (glide, plane-bed)</p> 	<p>Stretches of uniform and relatively featureless bed, comprising bedrock or coarse clasts (cobble or gravel). These smooth flow zones are either free-flowing or imposed shallow channel-like features that connect pools. They occur in both alluvial and bedrock-imposed situations. Individual boulders may protrude through otherwise uniform flow.</p>	<p>Plane-bed conditions promote relatively smooth conveyance of water and sediment. Slopes are intermediate between pools and riffles.</p>
<p>Forced riffle</p> 	<p>Longitudinally undulating gravel or boulder accumulations that act as local steps. Irregular spacing is dictated by the distribution of bedrock outcrops, wood or hillslope sediment inputs along the river. They tend to occur at wider sections of valley in bedrock-confined systems (e.g. at tributary confluences).</p>	<p>Flow is characterised by high-energy turbulence over lobate accumulations of coarse bedload materials, wood and bedrock outcrops. At the lower end of the energy spectrum, riffle–pool spacing in bedrock-confined settings may reflect purely rhythmic hydraulic processes of sediment transport.</p>

Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)



OR

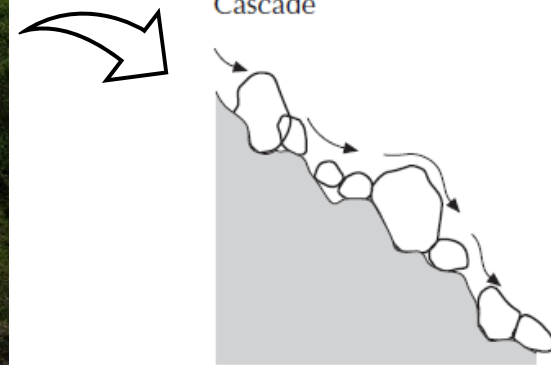
Rapid



??



Cascade

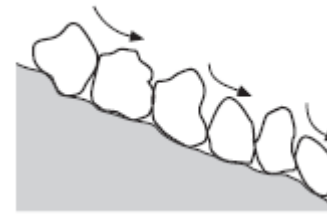


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Planar Continuum

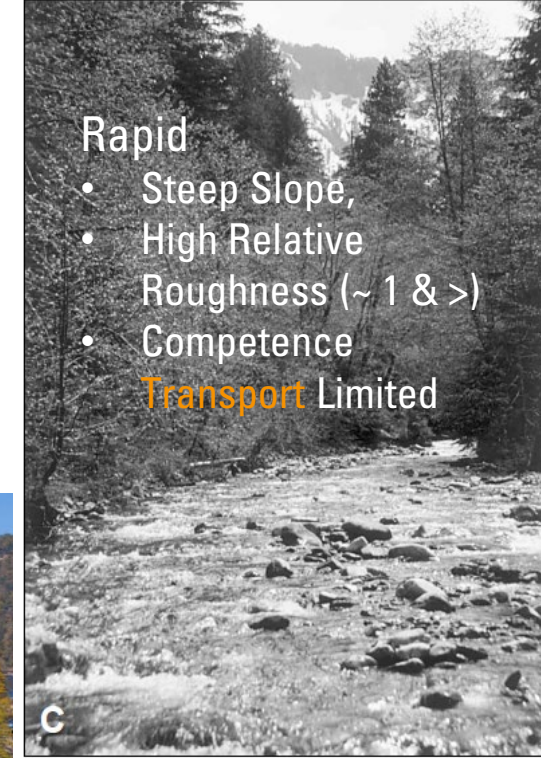
- Instead of “Sculpted, Erosional” think **transport** limited
- Continuum of Slope & Relative Roughness

Rapid



Rapid

- Steep Slope,
- High Relative Roughness (~ 1 & $>$)
- Competence **Transport** Limited



Run
(glide, plane-bed)



Run

- Intermediate Slope,
- Moderate Relative Roughness
- Competence **Transport** Limited



Cascade

- Really Steep Slope,
- Very High Relative Roughness (> 1)
- Competence **Transport** Limited



Glide

- Low Slope,
- Low Relative Roughness
- Capacity **Transport** Limited



Sediment
Transport Limited



capacity-limited channel



competence-limited channel

Sediment
Supply Limited



supply-limited channel where incision has occurred

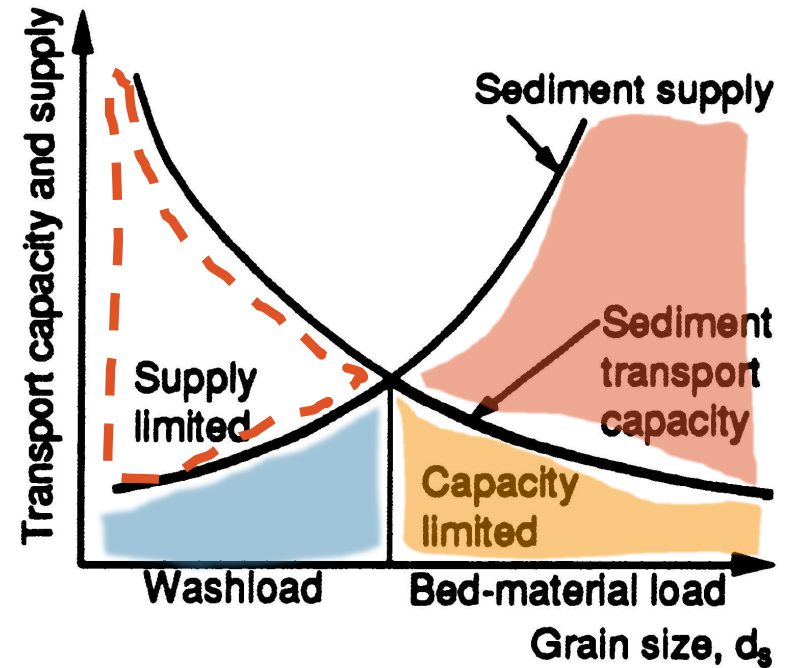
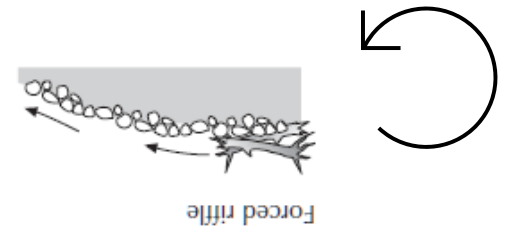


Figure 6.15 Sediment-supply- and transport-limited systems. Sediment transport volume or size exceeds the capacity of the flow to transport it, resulting in: Transport-limited systems can be competence (grain size is too large) or capacity-limited. Sediment-supply-limited systems occur when the flow is able to carry more sediment than is made available to it, resulting in erosion of sediment. Photographs: (a) Waiapu River, New Zealand (K. Fryirs), (b) Sangainotaki River, Japan (K. Fryirs), (c) Latrobe River, Victoria (G. Brierley), (d) Greendale Creek, NSW (K. Fryirs).

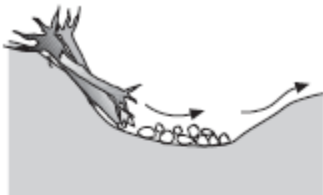
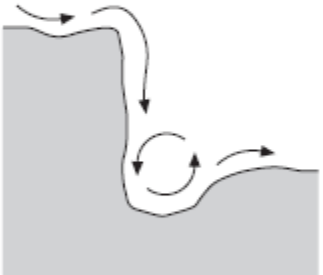
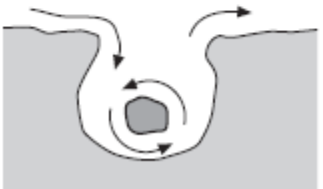
Structurally-Forced Riffle

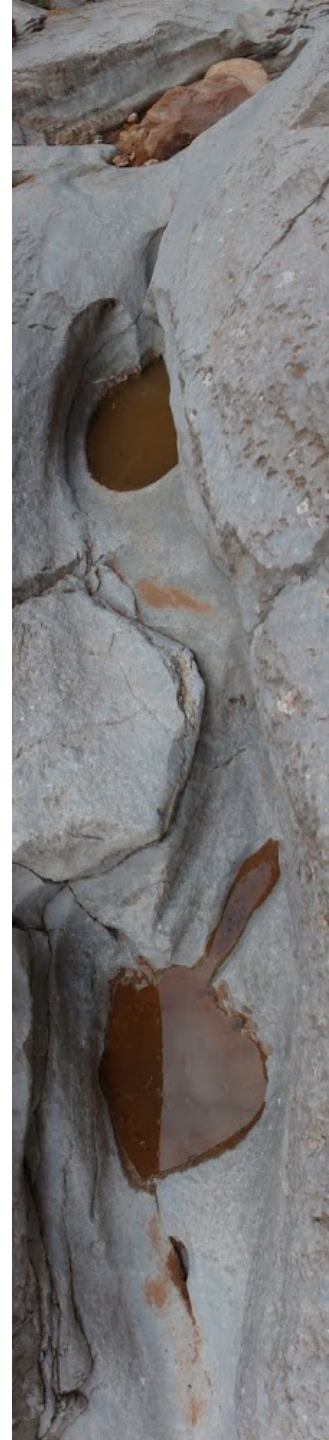
- Forms a riffle crest upstream of a channel spanning structural element

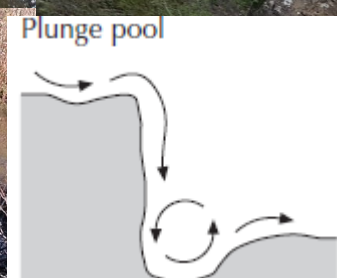
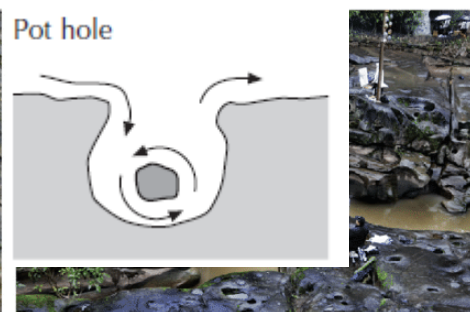
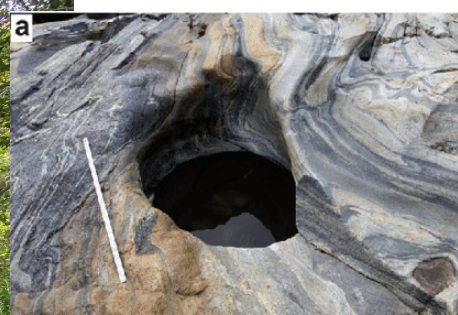
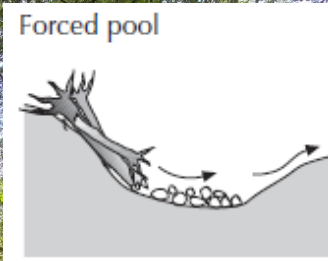


Pools as “Sculpted, Erosional” GUs

Table 8.1 (Continued)

Unit	Form	Process interpretation
<p>Forced pool</p> 	<p>These deeper areas along longitudinal profiles are scour features associated with irregularly spaced bedrock outcrops, wood and forced riffles. A <i>backwater pool</i> may form immediately upstream of a bedrock step.</p>	<p>These areas of tranquil flow within high-energy settings may accumulate finer grained materials at low-moderate flow stage, but they are flushed and possibly scoured during extreme events. At the lower end of the energy spectrum, riffle-pool spacing in bedrock-confined settings may reflect purely rhythmic hydraulic processes of sediment transport.</p>
<p>Plunge pool</p> 	<p>Deep, circular, scour feature formed at the base of a bedrock step.</p>	<p>As flow plunges over a step, its energy is concentrated and scour occurs by corrosion, cavitation and corrasion processes. Erosion may be aided by preweakening by weathering.</p>
<p>Pot hole</p> 	<p>Deep, circular scour features occur in bedrock.</p>	<p>Pot holes are sculpted from bedrock by corrasion (i.e. hydraulic and abrasive action of water). The effectiveness of this process is determined by the volume and hardness of particles that are trapped in the pothole. Abrasion is induced by these particles, which deepen and widen the pothole.</p>





Notion of Continuums of GUs

- Geomorphic unit occurrence is a slippery slope...
- Nuance of “dominant” vs. occurring

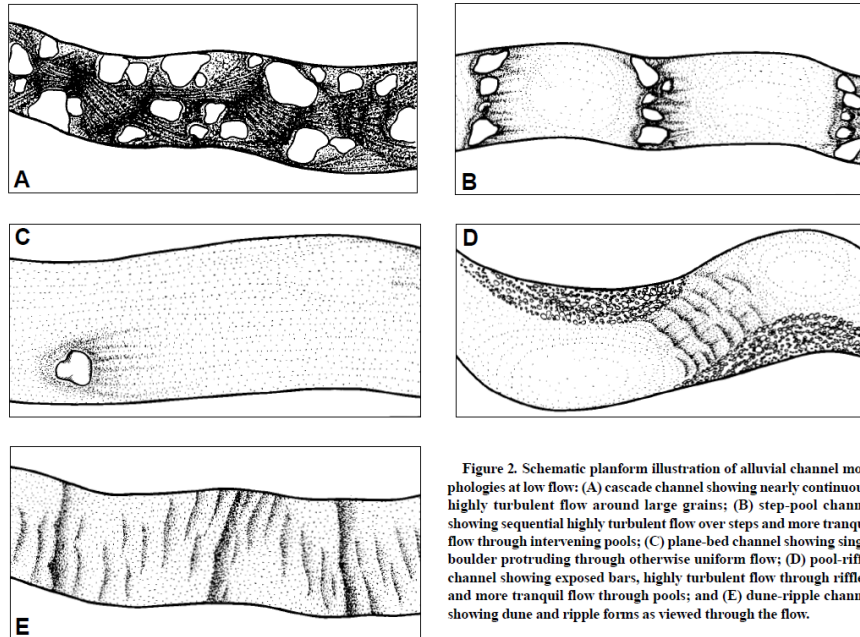
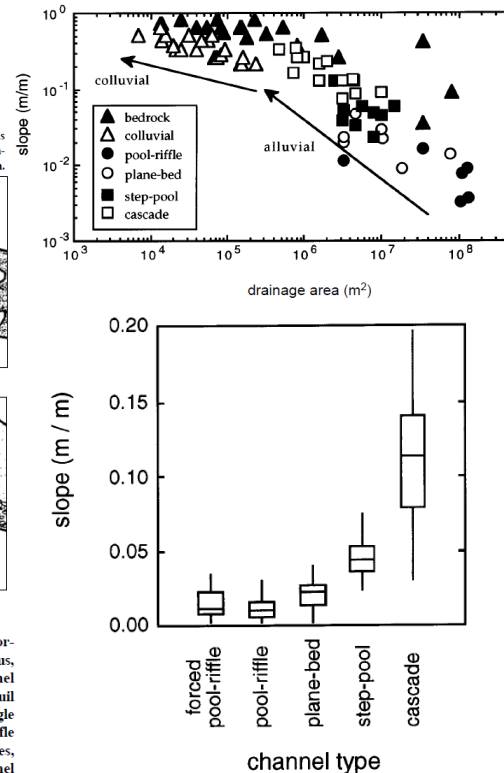


Figure 2. Schematic planform illustration of alluvial channel morphologies at low flow: (A) cascade channel showing nearly continuous, highly turbulent flow around large grains; (B) step-pool channel showing sequential highly turbulent flow over steps and more tranquil flow through intervening pools; (C) plane-bed channel showing single boulder protruding through otherwise uniform flow; (D) pool-riffle channel showing exposed bars, highly turbulent flow through riffles, and more tranquil flow through pools; and (E) dune-ripple channel showing dune and ripple forms as viewed through the flow.

Figure 5. Drainage area versus reach slope for channels in the Finney Creek watershed, Washington.



Montgomery & Buffington (1997) →

DOI: [10.1130/0016-7606\(1997\)109%3C0596:CRMIMD%3E2.3.CO;2](https://doi.org/10.1130/0016-7606(1997)109%3C0596:CRMIMD%3E2.3.CO;2)

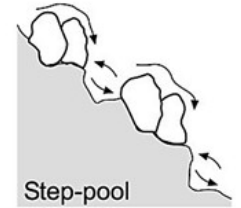
Fryirs & Brierley (2013) →

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

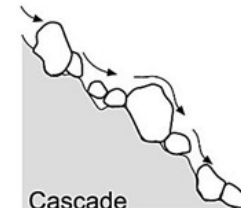
continuum of decreasing slope, stream power and grain size



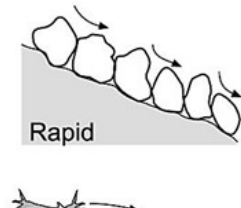
Waterfall / step with plunge pool



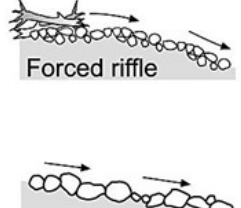
Step-pool



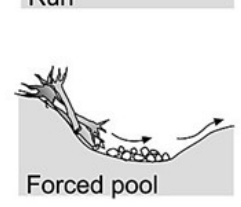
Cascade



Rapid



Forced riffle



Run



Forced pool

supply limited

transport limited

Figure 8.1 The continuum of sculpted, erosional instream geomorphic units. Downstream decreasing slope, stream power and grain size induce a transition from supply-limited features such as waterfalls, step-pool sequences, cascades and rapids through to transport-limited forms such as forced riffle-pool sequences and runs.

Instream Geomorphic Units

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 - I. Tier 1 – Stage
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- VI. GUT (Geomorphic Unit Toolkit)

Their first example of a mid-channel geomorphic unit is not ... it is channel spanning

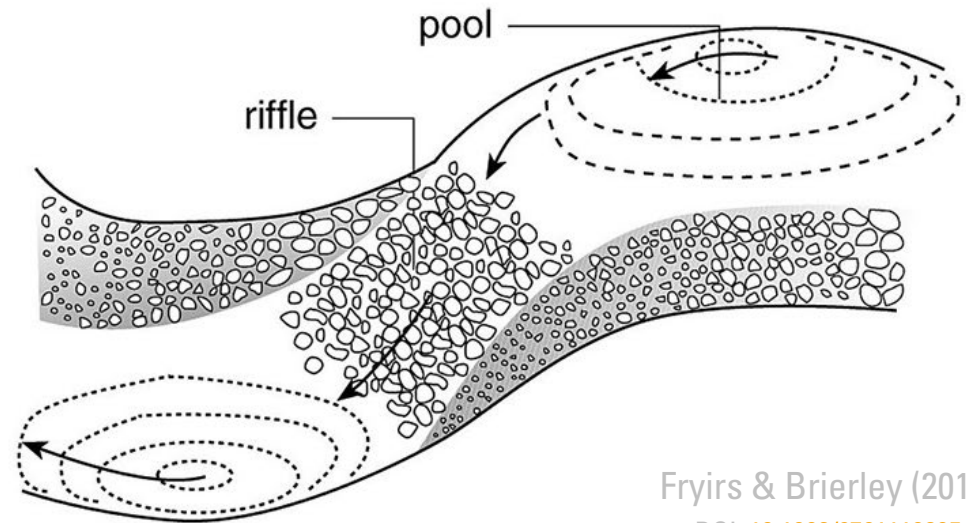
Table 8.2 Mid-channel geomorphic units^a

Unit	Form	Process interpretation
Riffle and pool	<p><i>Riffle</i></p> <p>Topographic highs along an undulating reach-scale longitudinal profile. They occur at characteristic locations, typically between bends (the inflection point) in sinuous alluvial channels. Clusters of gravel (up to boulder size) are organised into ribs, typically with a rippled water surface at low stage. Alluvial riffles are alternating shallow step-like forms that span the channel bed. These sediment storage zones tend to comprise tightly imbricated bed materials, suggesting the action of local sorting mechanisms. They induce local steepening of the bed.</p>	<p><i>Riffle</i></p> <p>Riffles are zones of temporary sediment accumulation which increase roughness during high flow stage, inducing deposition. Concentration of coarser fractions at high discharges (bankfull and above) produces incipient riffles, while lower flows (up to bankfull) may be sufficiently competent to amplify and maintain the initial undulations once they have reached a critical height. In subsequent high discharges, deposition occurs as the resistance of these features induces a reduction in velocity over the riffle surface. At high flow stage the water surface is smooth, as bed irregularities are smoothed out. Riffles are commonly dissected during the falling stage of floods, when the water surface is shallow and steep, and the stepped long profile is maintained. Although very stable, with 5–10% of the stream area in supercritical flow and some small hydraulic jumps over obstructions, riffles may be mobile at and above bankfull stage. Indeed, they may be removed and replaced during extreme floods, as they reform at lower flow stages (velocity reversal hypothesis).</p>

- Pool-riffle sequences very common, but that “genetic” linkage is not what defines a riffle.
- Pool-riffle literature vast
- We’ll revisit this in fluvial taxonomy

Pool-Riffles

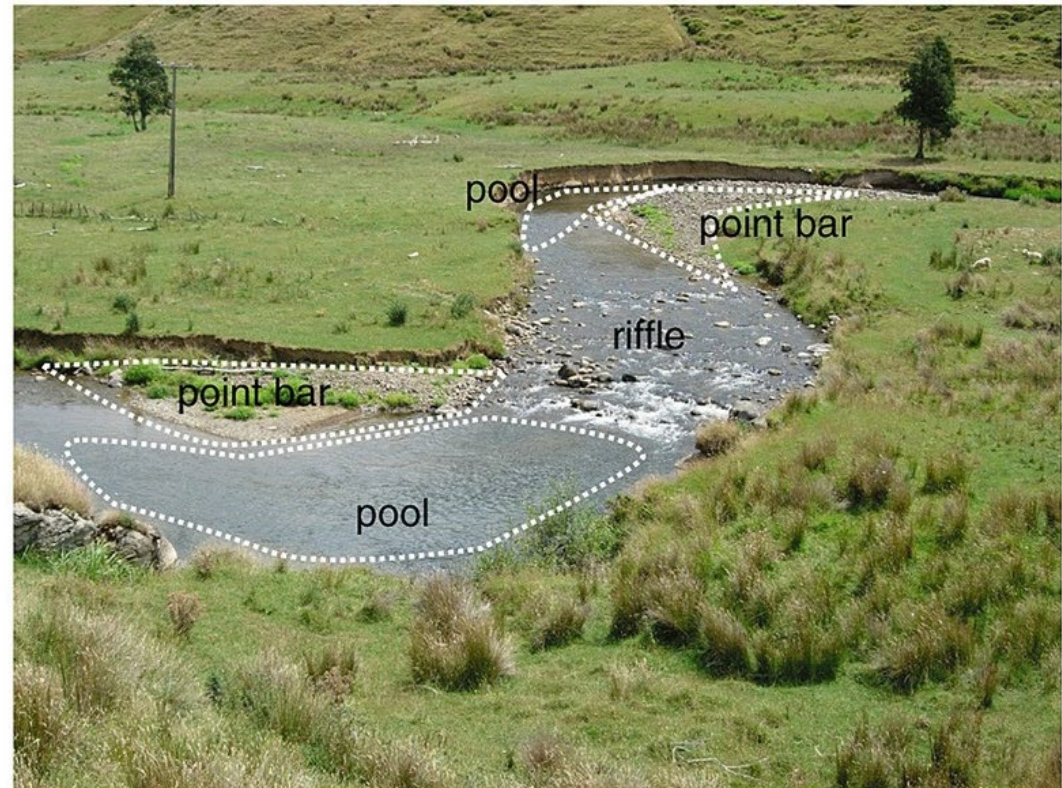
- This “classic” example of the pool-riffle-pool sequence with riffles connecting or spanning channel from point-bar to point bar is not only occurrence of “riffles”



Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Figure 8.3 Riffle-pool formation in meandering alluvial rivers. Accentuation of erosion on the concave bank of meander bends produces pools. Riffles form at the inflection points between bends, where sediment is deposited in shallower parts of the channel. Point bars occur on the insides of the bend as secondary flow moves sediment onto the bar surface. Down-bar (around the bend) gradation in grain size is commonly observed on these bar surfaces. Oparau River, New Zealand. Photograph: K. Fryirs.



Pools can be mid-channel, but not always

Pool

Pools may span the channel, hosting tranquil or standing flow at low flow stage. Alluvial pools are alternating deep areas of channel along an undulating reach-scale longitudinal bed profile. Pools tend to be narrower than riffles and act as sediment storage zones. They form at characteristic locations, typically along the concave bank of bends in sinuous alluvial channels.

Pool

At high flow stage, when flow converges through pools, decreased roughness and greater bed shear stresses induce scour and flushing of sediment stored on the bed. Subcritical flow occurs during divergent flow at low flow stage. Pool infilling subsequently occurs, as pools act as areas of deep, low flow velocity and near-standing water conditions. Pools and riffles are genetically linked in alluvial rivers. Velocity reversal at high flow stage maintains these features.



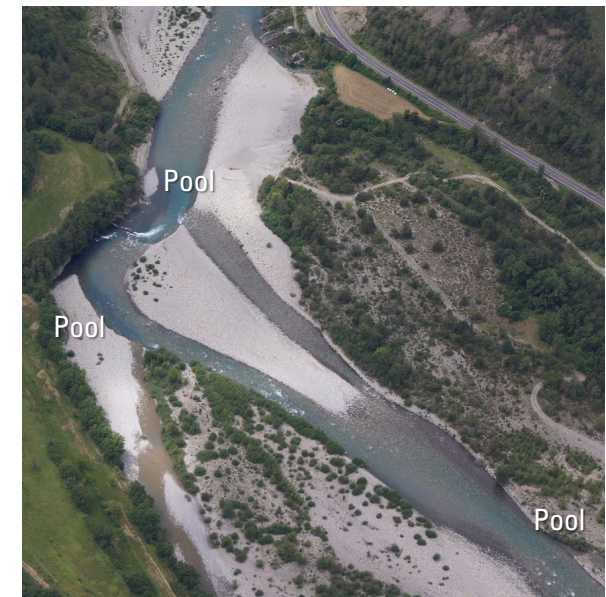
Dammed Pool



Bedrock step



Plunge Pool

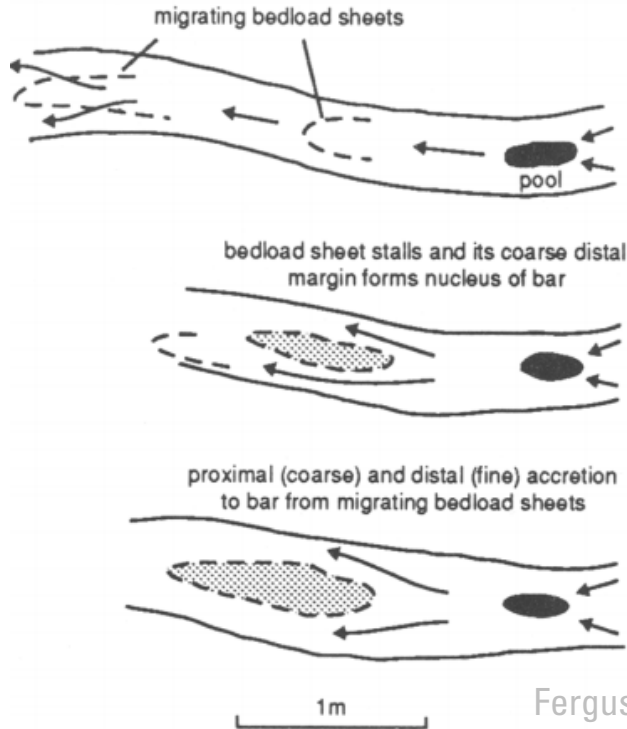


Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Longitudinal Bar – Flow splits symmetrically

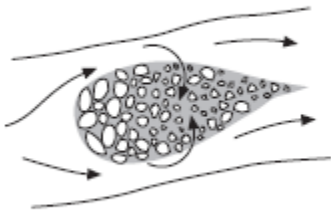
a : Central bar braiding



Ferguson (1993)

DOI: [10.1.1.834.1476](https://doi.org/10.1.1.834.1476)

Longitudinal bar
(medial bar)

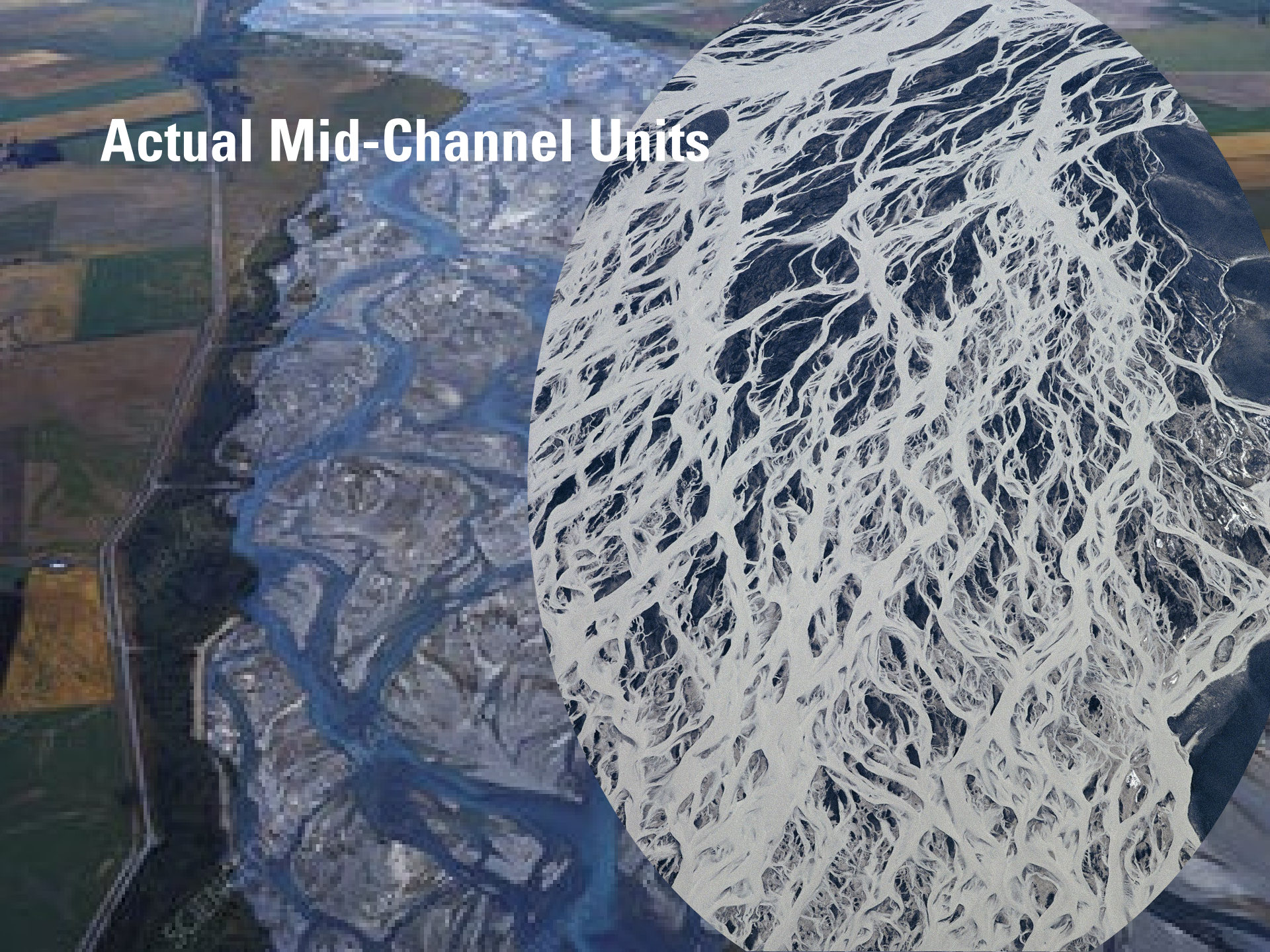


Mid-channel, elongate, tear-drop-shaped unit bar, aligned with flow direction in gravel- and mixed-bed channels. Bar deposits typically decrease in size downstream, away from a coarser bar head. May contain distinctly imbricated materials.

As flow diverges around the coarse bedload fraction it is no longer competent to transport sediment and materials are deposited in mid channel. Finer materials are trapped in the wake. Alternatively, there is too much sediment for the channel to transport (i.e. exceedence of a capacity limit under highly sediment-charged conditions) and material is deposited.



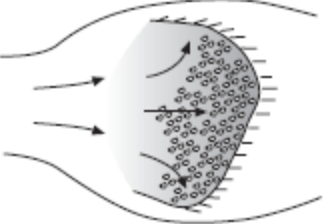
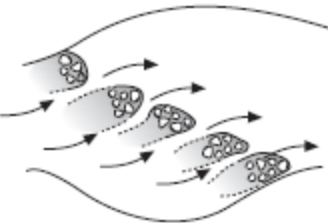
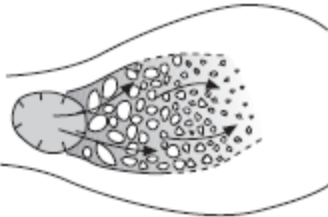
Actual Mid-Channel Units



So many Bars



Table 8.2 (Continued)

Unit	Form	Process interpretation
<p>Transverse bar (linguoid bar)</p> 	<p>Mid-channel unit bar, oriented perpendicular to flow, generally found at points of abrupt channel and flow expansion points in sand-bed channels. They have a lobate or sinuous front with an avalanche face. The upstream section of the bar is characterised by a ramp which may be concave in the centre and form an arcuate shape.</p>	<p>Formed via flow divergence in highly sediment-charged sandy conditions. Flow moves over the centre of the bar, diverges and is pushed up the ramp face. Sediment is pushed over the avalanche face and deposited on the lee side. As a result, the bar builds and moves downstream as a rib.</p>
<p>Diagonal bar (diamond bar)</p> 	<p>Mid-channel unit bar, oriented diagonally to banks in gravel- and mixed-bed channels. These bars commonly have an elongate, oval or rhomboid planform. Particle size typically fines down-bar. Commonly associated with a dissected riffle.</p>	<p>Formed where flow is oriented obliquely to the longitudinal axis of the bar. May indicate highly sediment-charged conditions or reworking of riffles.</p>
<p>Expansion bar</p> 	<p>Coarse-grained (up to boulder size) mid-channel bar with a fan-shaped planform. A streamlined ridge forms trail behind obstructions. Foreset beds commonly dip downstream with a very rapid proximal–distal grain-size gradation. Often occur downstream of a bedrock constriction that hosts a forced pool. May be colonised and stabilised by vegetation.</p>	<p>As flow expands abruptly at high flood stage in high-energy depositional environments, it loses competence and induces deposition. Dissection is common at falling stage. These bars remain fairly inactive between large floods, constraining processes at lower flow stages.</p>

Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Mid-Channel Bars

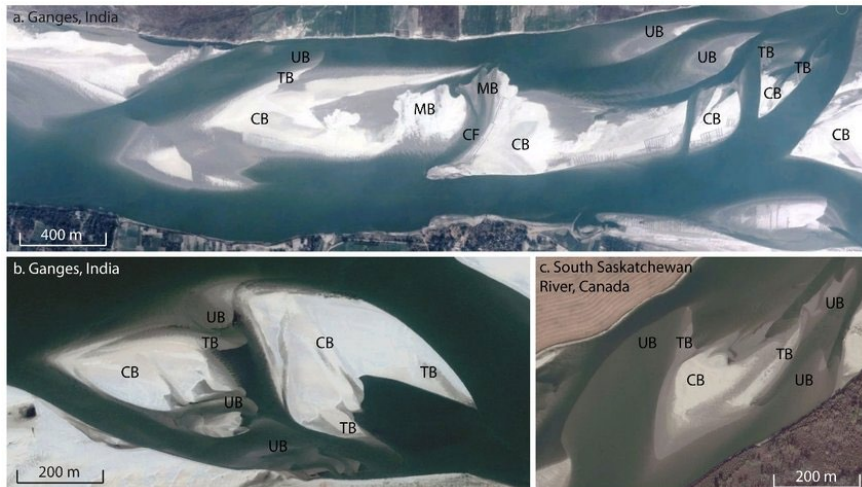
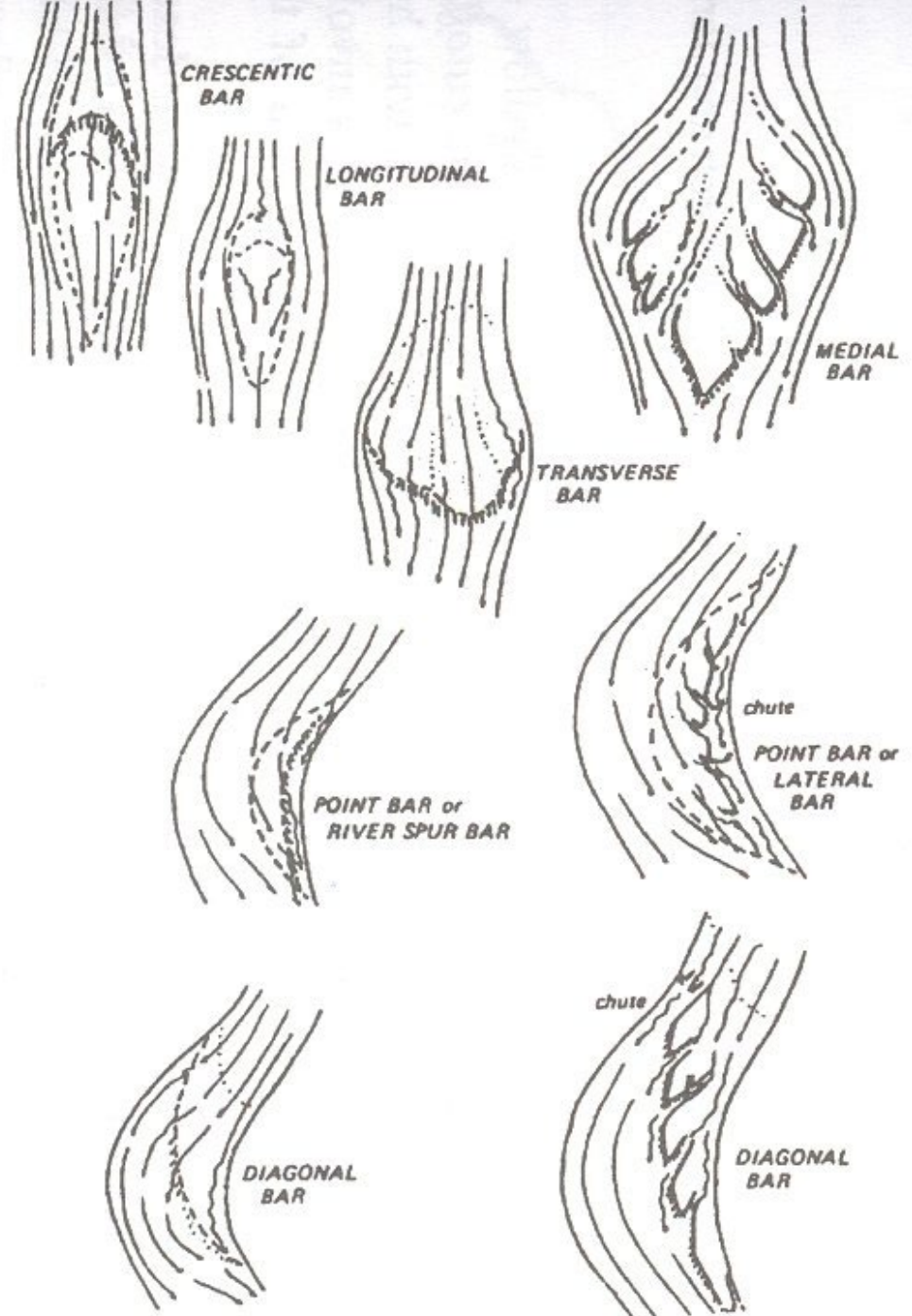
Schuurman (2015)

DOI: [10.13140/RG.2.1.3582.3529](https://doi.org/10.13140/RG.2.1.3582.3529)



Differentiated by

- Position
- Formation

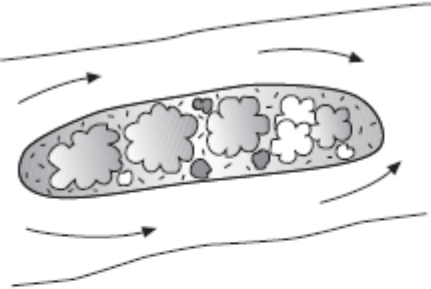
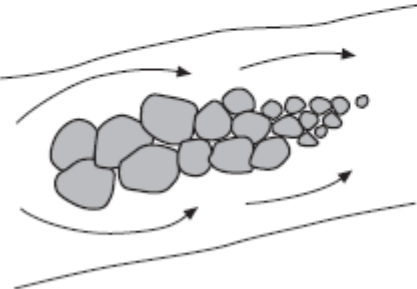


Schuurman (2015)

DOI: [10.13140/RG.2.1.3582.3529](https://doi.org/10.13140/RG.2.1.3582.3529)

Islands & Boulder Mounds

Table 8.2 (Continued)

Unit	Form	Process interpretation
Island	 <p>Vegetated mid-channel bar. Can be emergent at bankfull stage. Generally compound forms, comprising an array of smaller scale geomorphic units. They are commonly elongate in form, aligned with flow direction scaling to one or more channel widths in length.</p>	<p>Generally form around a bar core that has been stabilised by vegetation. This induces further sedimentation on the island. Islands are differentiated from bar forms by their greater size and persistence, reflecting their relative stability and capacity to store instream sediments. The pattern of smaller scale geomorphic units reflects the history of flood events and processes which form and rework the island.</p>
Boulder mound	 <p>Linguoid-shaped boulder feature with a convex surface cross-section. Comprise a cluster of boulders without matrix, fining in a downstream direction.</p>	<p>Deposited under high-velocity conditions. When the competence limit of the flow drops, the coarsest boulders are deposited, forming obstructions to flow. Secondary lee circulation occurs in the wake of the coarse clasts. Finer boulders and pebbles are subsequently deposited downstream of the core clasts, resulting in distinct downstream fining.</p>

(Continued)

Island - Split flow around > bankfull



Island

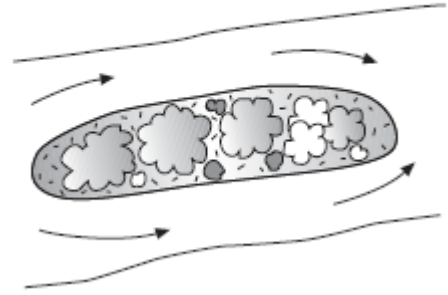
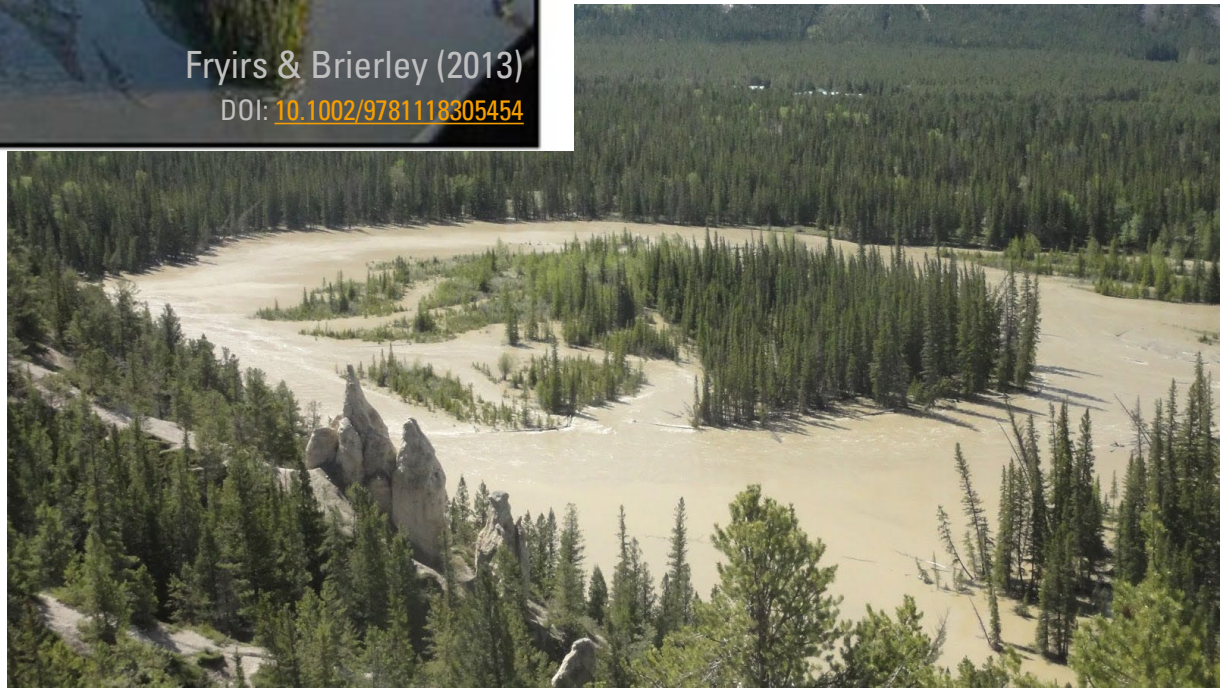


Figure 8.4 Other types of mid-channel geomorphic units. (a) Islands are vegetated bars, (b) bedrock core bars/islands occur where vegetation grows on finer substrates deposited on bedrock outcrops and (c) forced bars occur where obstructions such as wood or vegetation induce deposition in the middle of the channel bed. (a) Roger W. Ruess, Institute of Arctic Biology, University of Alaska; www.iab.uaf.edu/research/research_project_by_id.php?project_id=171. (b) Kruger National Park, South Africa. Photograph: G. Brierley, (c) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs.



The World's most common Mid-Channel Bar



- Any guesses?



Diagonal Bars, Start Life as Bank-Attached

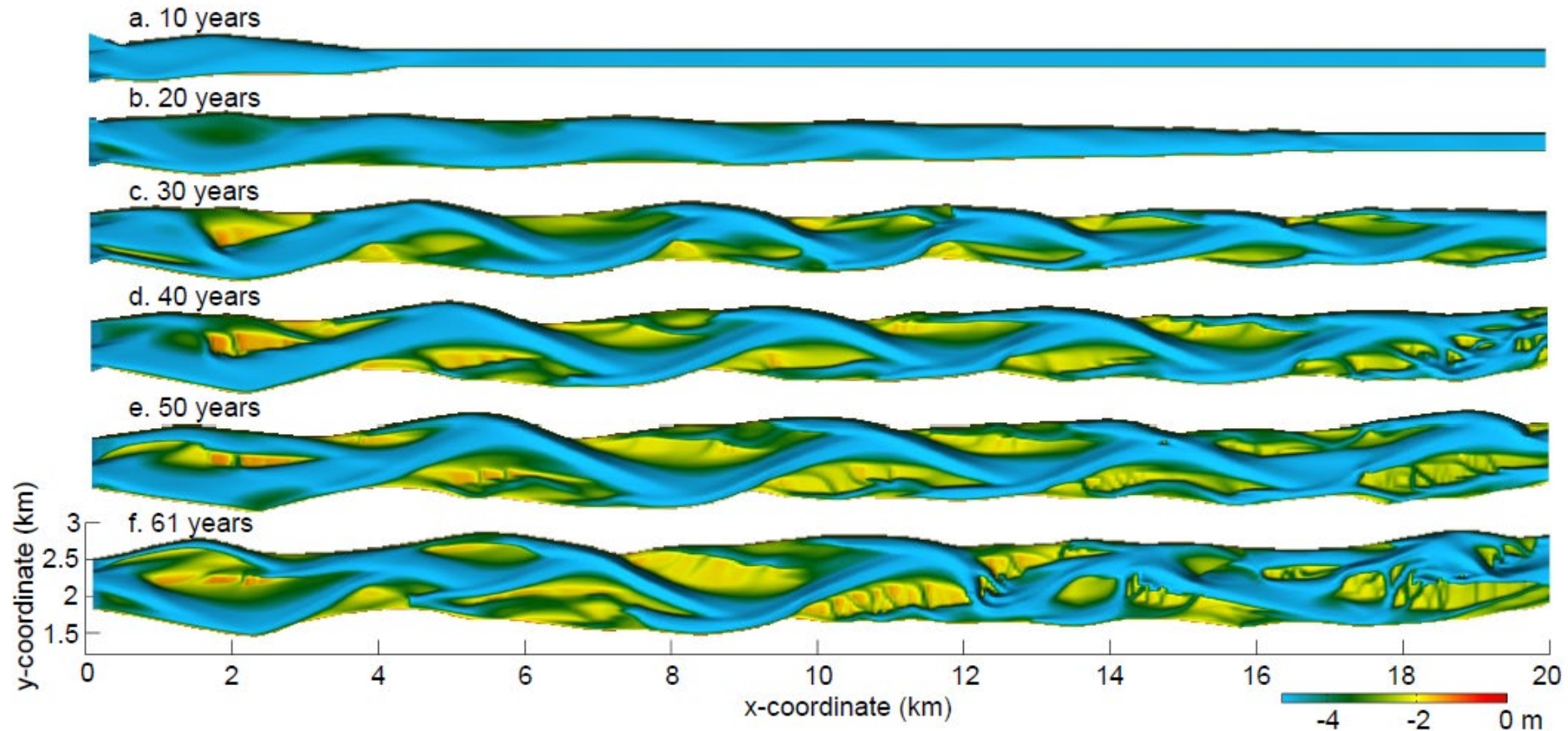


Figure 4.4: *Initiation and evolution of alternate bars and incipient meandering in run D3D-A3, with continuous upstream inflow migration and erodible banks. After around 40 years, mid-channel bars formed by chute-cutoffs.*

Diagonal Bar

- Diagonal bars are a mid-channel bar that starts out as a bank-attached point bar, but then becomes mid-channel via the process of chute cutoff...



- Their name describes flow across them (@ higher stages), which flows diagonally from a higher anabranch to a lower anabranch

Keys to Identifying Diagonal Bars

1. Identify 'inside bend' of flow
2. Identify the flow separation point.
3. Trace a high-stage flow seam to a reattachment zone
4. Identify the 'mid-channel' bar within the shear zone (i.e. is it separated by a chute cutoff along inside channel margin)
5. Confirm flow is diagonal across bar from 'high' to 'low' anabranch at higher stages.

- ★ Flow Separation Point (AKA detachment point)
● Reattachment Point Shear Zone

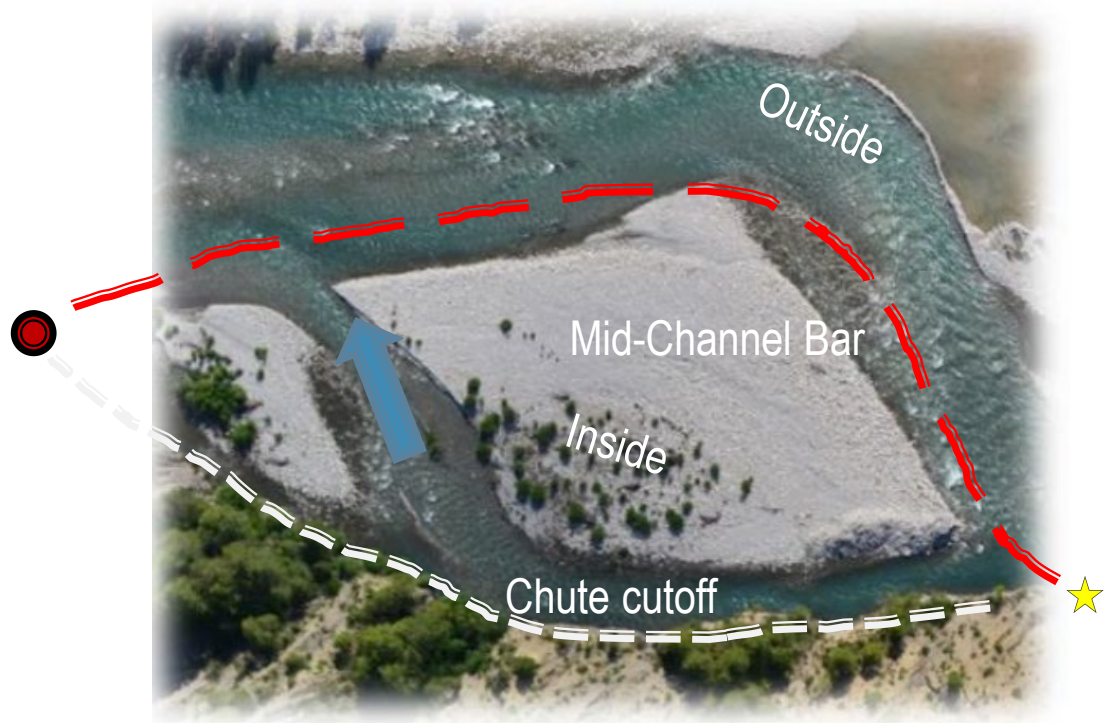

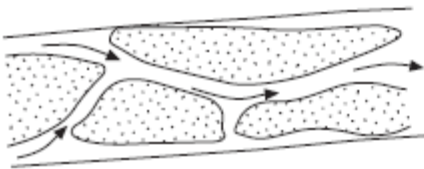
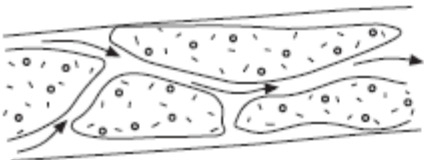


Table 8.2 (Continued)

Unit	Form	Process interpretation
<p>Bedrock core bar</p> 	<p>Elongate bedrock ridge over which sediments have been draped and colonised by vegetation. Sediments become finer grained downstream, and the age structure of the vegetation gets younger.</p>	<p>During the waning stages of large flood events, sediments are deposited on top of an instream bedrock ridge. When colonised by vegetation, additional sediment is trapped and accumulates on top of the bedrock core. Over time the bar builds vertically and longitudinally as sediments are trapped in the wake of vegetation.</p>
<p>Sand sheet</p> 	<p>Relatively homogeneous, uniform, tabular sand deposits which cover the entire bed. May consist of an array of bedforms, reflecting riffle, dune or plane-bed sedimentation.</p>	<p>Formed when transport capacity is exceeded or competence is decreased and bedload deposition occurs across the bed. Generally reflect transport- and capacity-limited conditions due to an oversupply of sediment. Bedforms are regularly reworked and replaced as the sand sheet moves downstream as a pulse.</p>
<p>Gravel sheet (basal or channel lag)</p> 	<p>Relatively homogeneous, thin/ tabular bedload sheets that are deposited across the bed. Often coarse grained and poorly sorted. May consist of an array of gravel bedforms such as pebble clusters and ribs.</p>	<p>Deposited under uniform energy conditions in highly sediment-charged rivers. Generally indicates transport- and capacity-limited or competence-limited conditions due to oversupply of sediment. Surficial gravel bedforms are frequently reworked as the sheet moves downstream as a pulse. May represent residual deposits that form a basal lag or a diffuse gravel sheet, reflecting rapid deposition and/or prolonged winnowing. May be armoured.</p>

Bedrock Core Bar



Figure 8.4 Other types of mid-channel geomorphic units. (a) Islands are vegetated bars, (b) bedrock core bars/islands occur where vegetation grows on finer substrates deposited on bedrock outcrops and (c) forced bars occur where obstructions such as wood or vegetation induce deposition in the middle of the channel bed. (a) Roger W. Ruess, Institute of Arctic Biology, University of Alaska; www.iab.uaf.edu/research/research_project_by_id.php?project_id=171. (b) Kruger National Park, South Africa. Photograph: G. Brierley, (c) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs.

Bedrock core bar



Elongate bedrock ridge over which sediments have been draped and colonised by vegetation. Sediments become finer grained downstream, and the age structure of the vegetation gets younger.

During the waning stages of large flood events, sediments are deposited on top of an instream bedrock ridge. When colonised by vegetation, additional sediment is trapped and accumulates on top of the bedrock core. Over time the bar builds vertically and longitudinally as sediments are trapped in the wake of vegetation.

Fryirs & Brierley (2013)

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Mid-Channel Units on Continuum of Q_s

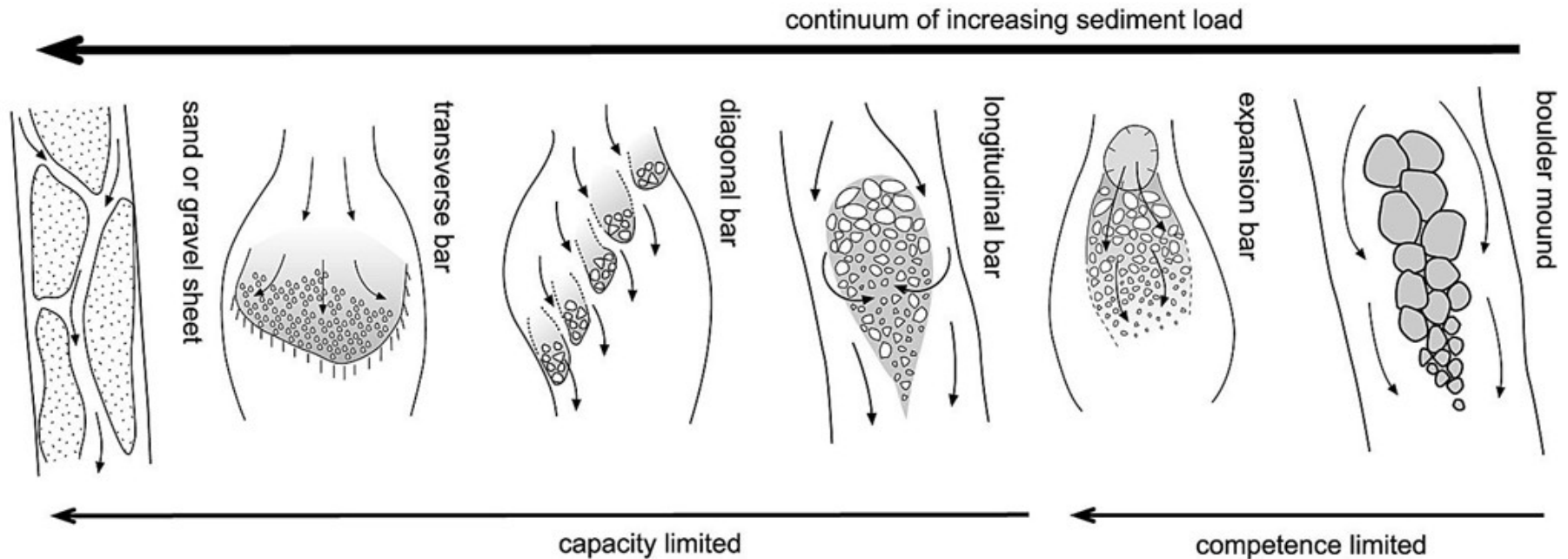
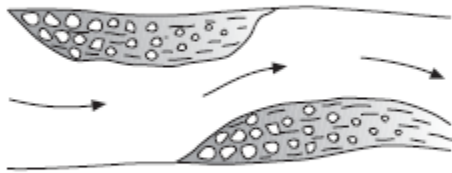
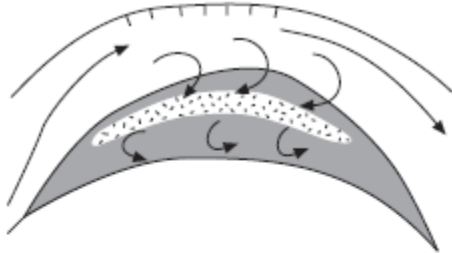


Figure 8.2 The continuum of mid-channel geomorphic units. The continuum occurs along a gradient of increasing sediment load, extending from coarse-grained boulder mounds in competence-limited conditions, to longitudinal and transverse bars and sand sheets under capacity-limited conditions.

Instream Geomorphic Units

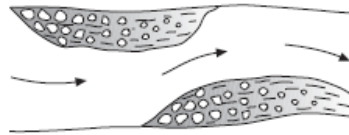
- I. Intro → Geomorphic Units & Process-Form Associations
- II. Classification & Field Identification
- III. Your Book (River Styles)**
 - I. Sculpted, Erosional Bedrock & Boulder GUs
 - II. Mid-Channel, Depositional GUs
 - III. Bank-Attached, Depositional GUs**
 - IV. Sculpted, Erosional Fine-Grained GUs
 - V. Unit & Compound GUs
 - VI. Forced GUs
- IV. Continuum of GUs
- V. Fluvial Taxonomy GUs (Topographically Defined)
 - I. Tier 1 – Stage
 - II. Tier 2 – Shape / Form
 - III. Tier 3 – Attributed
- VI. GUT (Geomorphic Unit Toolkit)

Table 8.3 Bank-attached geomorphic units^a

Unit	Form	Process interpretation
<p>Lateral bar (alternate or side bar)</p> 	<p>Bank-attached unit bar developed along low-sinuosity reaches of gravel- and mixed-bed channels. Bar surface is generally inclined gently towards the channel. These bars occur on alternating sides of the channel. They are generally longitudinally asymmetrical and may or may not have an avalanche face on the downstream side.</p>	<p>Flow along a straight reach of river adopts a sinuous path. Bar length and width are proportional to these flows. Bar height is dictated by flow depth. Bars form by lateral or oblique accretion processes, with some suspended-load materials atop (i.e. typically upward fining depositional sequence). They generally migrate in a downstream direction.</p>
<p>Scroll bar</p> 	<p>Elongate ridge form developed along the convex bank of a bend. Commonly develop on point bars with an arcuate morphology.</p>	<p>Formed by two-dimensional flow paths on the inside of a bend. Adjacent to the thalweg, sand or gravel bedload material is moved by traction towards the inner sides of channel bends via helicoidal flow. This is accompanied by a separation zone adjacent to the bank formed at near-bankfull stage, which shifts flow alignment adjacent to the bank. Convergence of these flow paths leads to the deposition of a ridge-like feature on the point bar surface. Associated with laterally migrating channels, scroll bars reflect the former position of the convex bank. With progressive channel shift and stabilisation by vegetation, scrolls develop into ridge and swale topography.</p>

Lateral Bars

Lateral bar
(alternate or side bar)



Bank-attached unit bar developed along low-sinuosity reaches of gravel- and mixed-bed channels. Bar surface is generally inclined gently towards the channel. These bars occur on alternating sides of the channel. They are generally longitudinally asymmetrical and may or may not have an avalanche face on the downstream side.

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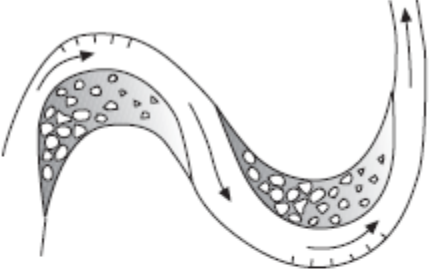
Figure 8.5 Bank-attached geomorphic units. (a) Lateral bars are formed in low-sinuosity reaches and (b) point bars on meander bends. (c) Benches are depositional features reflecting channel contraction, while (d) ledges are erosional features reflecting channel expansion. (e) Concave bank benches form in separation zones where flow impinges against bedrock on a concave bank. (a) Lerida Creek, NSW. Photograph: K. Fryirs. (b) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery. (c) Tuross River, NSW. Photograph: K. Fryirs. (d) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (e) Luangwa River, Zambia. Photograph: Gilvear *et al.* (2000).

Fryirs & Brierley (2013)

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Most Bank-Attached GUs from flow separations

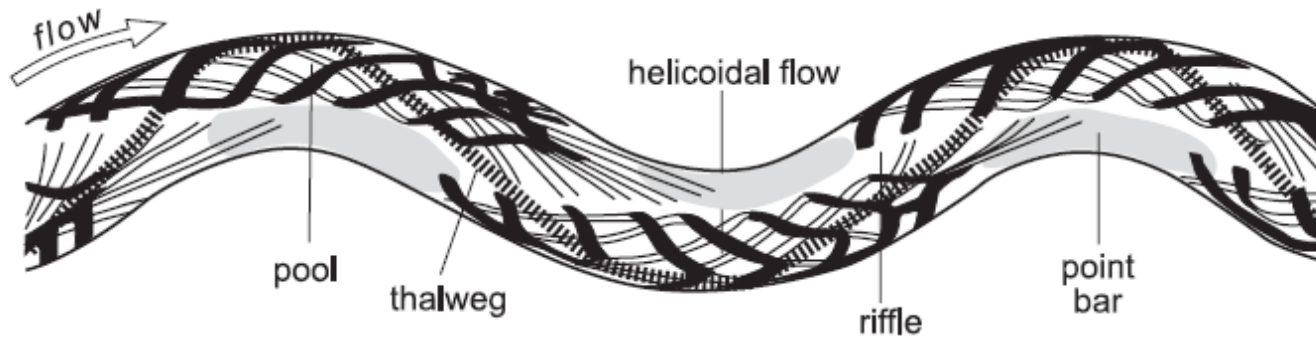
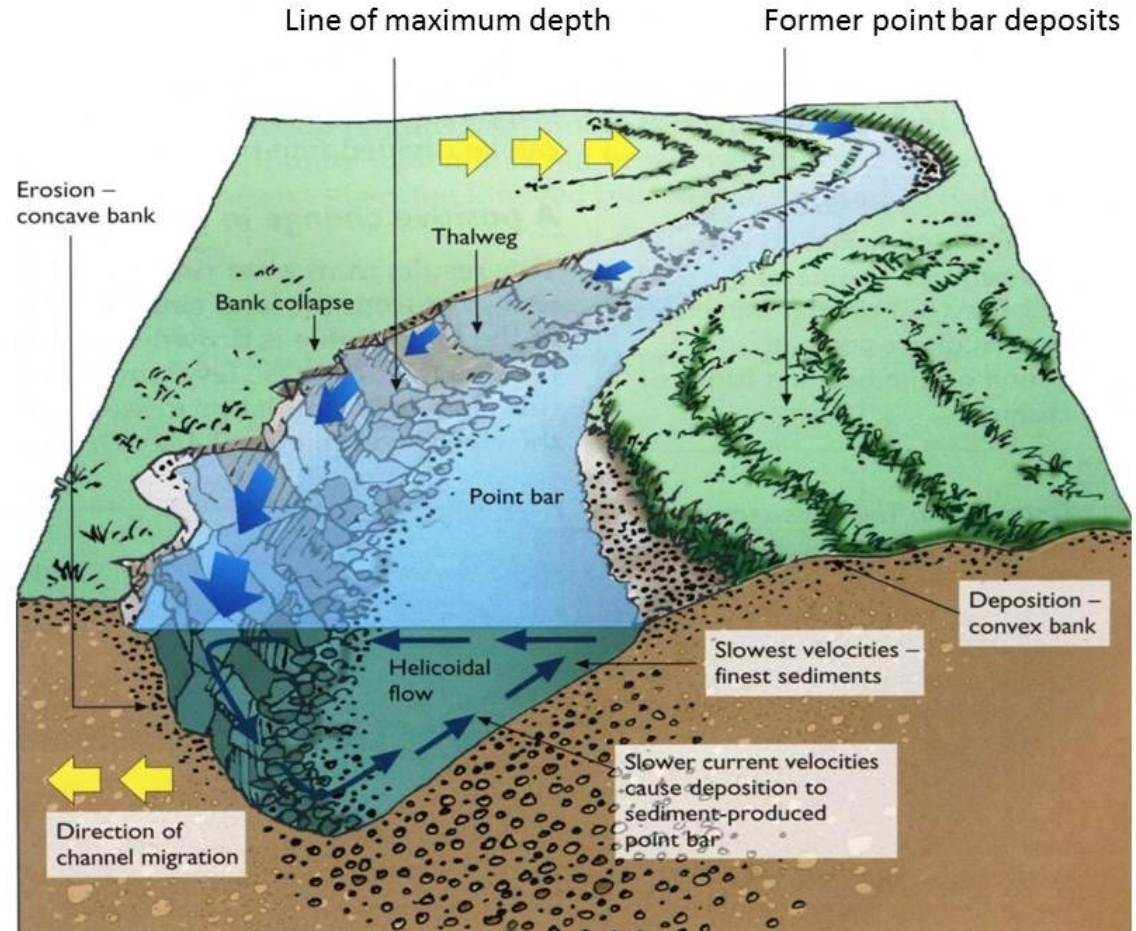
Table 8.3 Bank-attached geomorphic units^a

Unit	Form	Process interpretation
Point bar	 <p>Bank-attached arcuate-shaped bar developed along the convex banks of meander bends. Bar forms follow the alignment of the bend, with differing radii of curvature. The bar surface is typically inclined towards the channel, as are the sedimentary structures. Grain size typically fines down-bar (around the bend) and laterally (away from the channel). Typically these unit bar forms are unvegetated.</p>	<p>Result from lateral shift in channel position associated with deposition on the convex bank and erosion on the concave bank. Sand or gravel bedload material is moved by traction towards the inner sides of channel bends via helicoidal flow. Differing patterns of sedimentation are imposed by the radius of curvature (bend tightness) as well as the flow regime and sediment load. The coarsest material is deposited from bedload at the bar head, where the thalweg is aligned adjacent to the convex bank (at the entrance to the bend). As the thalweg moves away from the convex bank down-bar, lower energy suspended-load materials are deposited in secondary flow circulation cells, as the propensity for deposition is increased. Secondary flow also forces material up onto the face of the bar, building it laterally.</p>

- Forms on inside bend from flow separation and inside “shear zone”

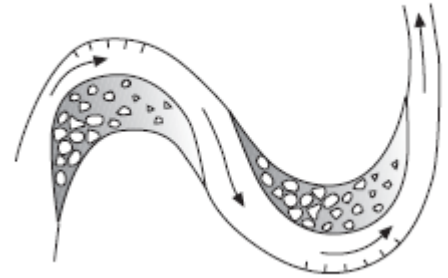
Recall

- Flow separation point
- Flow Seam
- Shear Zone (wake or eddy)
- Reattachment Zone
- Helicoidal flow structures in meander bends produce an anticlockwise, corkscrew effect.



Point Bar

Point bar



- Infer the unit-forming hydraulics...

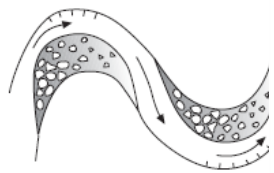
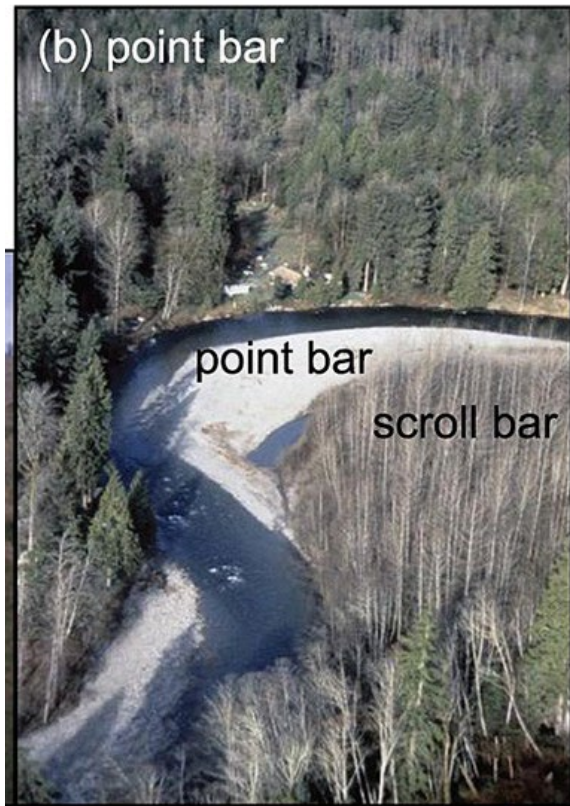


Figure 4.1: Examples of a. High-sinuosity meandering river characterized by abundance of vegetation along the river, a lack of bars, and neck-cutoffs (Rio Purus, Brazil); b. Low-sinuosity meandering river with low vegetation density and chute-cutoffs (Allier, France); c. Meandering river with bars forced by channel curvature (Wabash River, USA); d. Meander bend with free bars, including mid-channel bars (Rio Parnaíba, Brazil); e. Low-sinuosity river with free alternate bars (Cross River, Nigeria); f. Asymmetrical shape of the alternate bars with bar-tail limbs at the downstream (Indus River, Pakistan). Flow in all examples is from left to right. Source:

Active Meandering

- Point bar development on inside bends with enough bank cohesion on outside bend



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Figure 8.5 Bank-attached geomorphic units. (a) Lateral bars are formed in low-sinuosity reaches and (b) point bars on meander bends. (c) Benches are depositional features reflecting channel contraction, while (d) ledges are erosional features reflecting channel expansion. (e) Concave bank benches form in separation zones where flow impinges against bedrock on a concave bank. (a) Lerida Creek, NSW. Photograph: K. Fryirs. (b) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery. (c) Tuross River, NSW. Photograph: K. Fryirs. (d) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (e) Luangwa River, Zambia. Photograph: Gilvear *et al.* (2000).

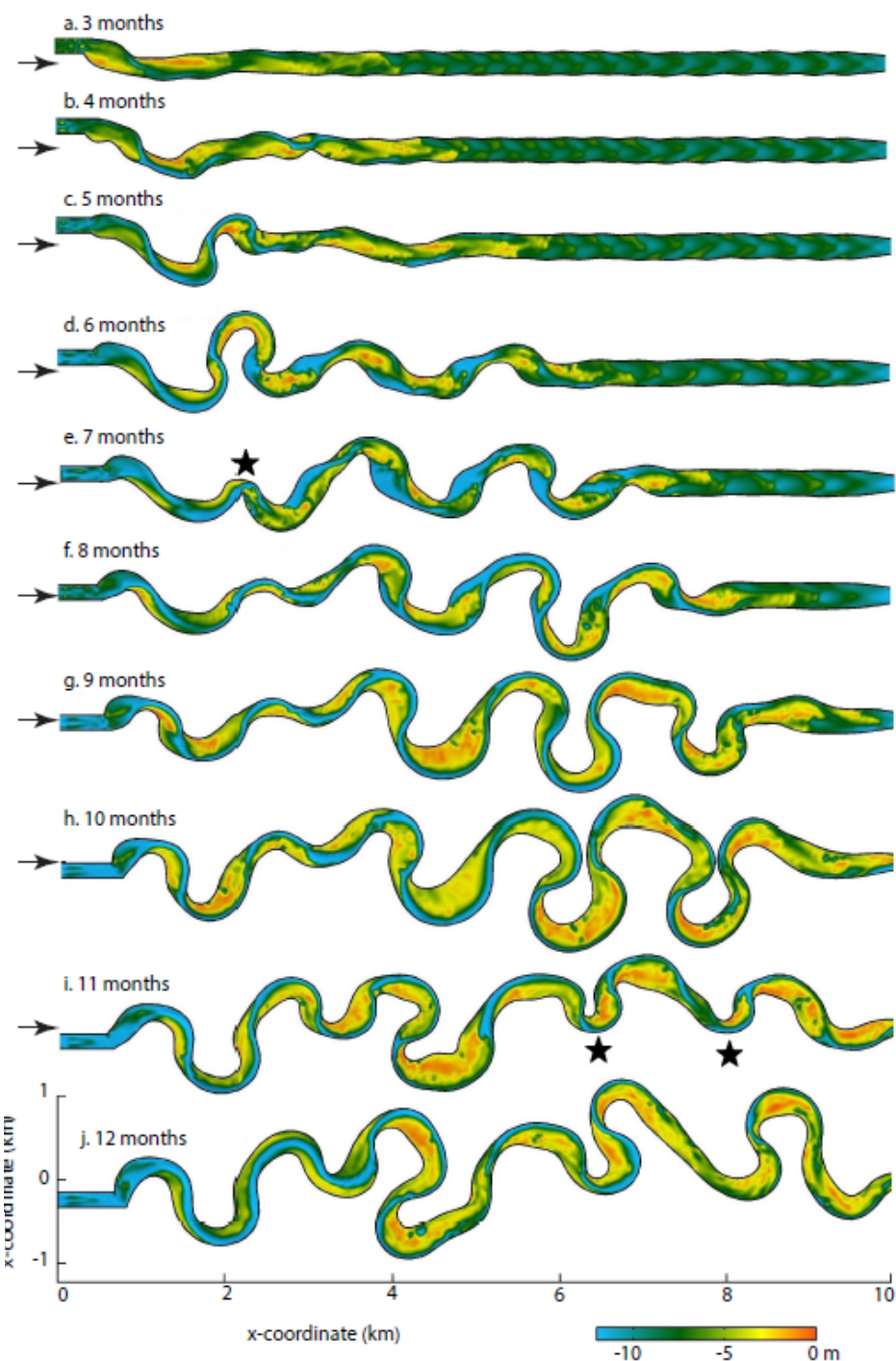
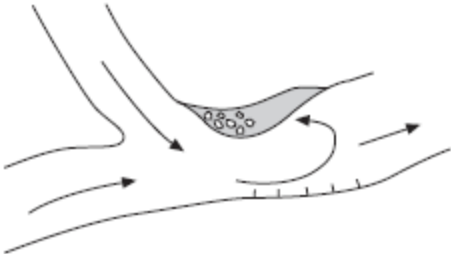
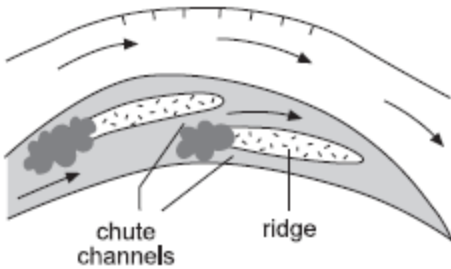
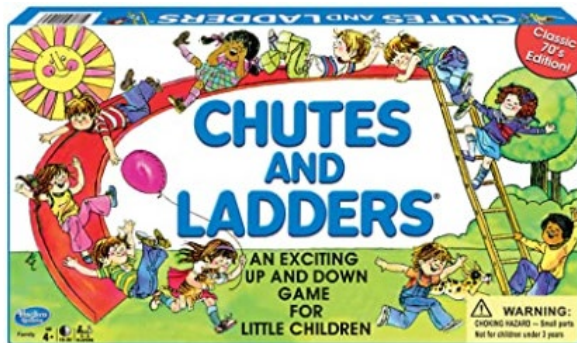


Table 8.3 (Continued)

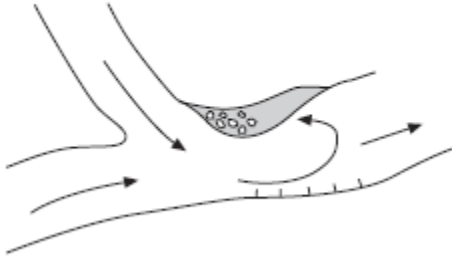
Unit	Form	Process interpretation
<p>Tributary confluence bar (channel junction bar, eddy bar)</p> 	<p>Formed at, and immediately downstream of, the mouth of tributaries. These delta-like features have an avalanche face. They generally comprise poorly sorted gravels and sands with complex and variable internal sedimentary structures. They represent a form of slackwater deposit (interbedded sands and mud) that is not elevated above the channel and is prone to reworking.</p>	<p>Typically form at high flood stage in reaches where a comparatively minor tributary enters the trunk channel. Flow separation and generation of secondary currents in the backwater zones promote sedimentation in sheltered areas under low flow velocity conditions.</p>
<p>Ridge and chute channels (cross-bar channels)</p> 	<p><i>Ridge</i> Linear, elongate deposit formed atop a bar platform on a mid-channel or bank-attached bar. May be curved or relatively straight. Deposits tend to fine down-ridge. May be formed downstream of vegetation or other obstructions on the bar surface.</p> <p><i>Chute channel</i> Elongate, relatively straight channel that dissects a bar surface. Usually initiated at the head of the bar. Commonly found on bank-attached, mid-channel bars and islands, where they form compound features.</p>	<p><i>Ridge</i> Ridge morphology and alignment atop bar surfaces reflect the character of channel adjustment over the bar at high flow stages. Vegetation promotes ridge development with sediment being deposited in the wake.</p> <p><i>Chute channel</i> Develop as water flows over a formerly emergent bar surface. Scour occurs during the rising stage of over-bar flows. If the bar is short-circuited, flow energy is concentrated, inducing scour that reworks the bars and forms a chute channel.</p>



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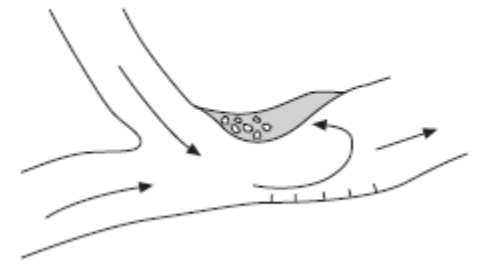
Tributary confluence bar
(channel junction bar, eddy bar)



Channel Junction Bar



Tributary confluence bar
(channel junction bar, eddy bar)



- Like a mini-alluvial fan

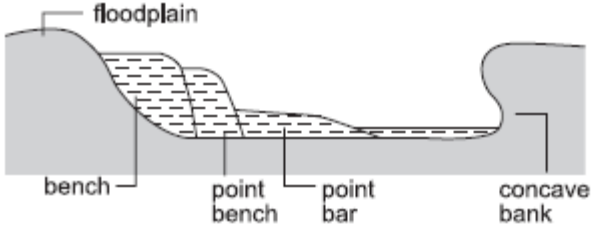
Figure 8.6 Other types of bank-attached geomorphic units. (a) Bars may occur at tributary confluences, or as (b) berms and (c) point dunes. (d) Forced bars occur where obstructions such as wood or vegetation lead to deposition against the channel bank. (a) Tongariro River, New Zealand. Photograph: P. Chappell. (b) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (c) Kangaroo River, NSW. Photograph: K. Fryirs. (d) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery.

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Benches

Table 8.3 (Continued)

Unit	Form	Process interpretation
<p>Bench and point bench (oblique-accretion bench)</p> 	<p><i>Bench</i> A distinctly stepped, elongate, straight to gently curved feature that is inset along a bank. These significant in-channel sediment storage units are often situated atop bar deposits. They may comprise obliquely attached mud-rich drapes with a convex geometry in suspended-load systems, or obliquely and vertically accreted sand deposits in bedload systems. Sedimentary structures tend to be quite distinct from the floodplain.</p> <p><i>Point bench</i> Distinctly stepped, bank-attached unit developed along the convex bank of a sinuous channel. Typically has an arcuate planform with a planar surface that is elevated above the point bar.</p>	<p><i>Bench</i> Formed by oblique- and vertical-accretion of bedload and suspended-load materials during small to moderate floods within widened channels. During the rising stage of flood events, bedload materials are deposited atop step-like features. During the waning stages, suspended-load materials are deposited as flood couplets atop bedload materials. Oblique accretion benches represent low-energy falling-stage suspended-load deposition in sand-bed and mud-rich streams. Deposition is often promoted by riparian vegetation. Benches are a major agent of channel contraction in overwidened channels.</p> <p><i>Point bench</i> Deposition along the convex bank via vertical and/or oblique accretion of interbedded sands and mud indicates slow lateral migration or lateral accretion within an overwidened bend.</p>

Benches



Bench and point bench
(oblique-accretion bench)

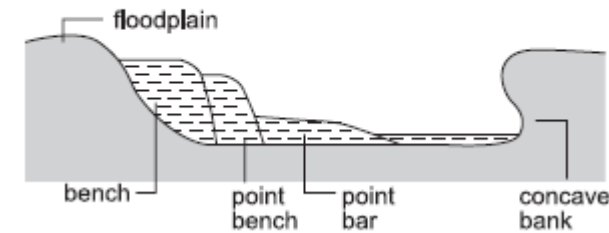
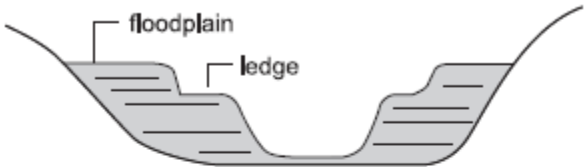
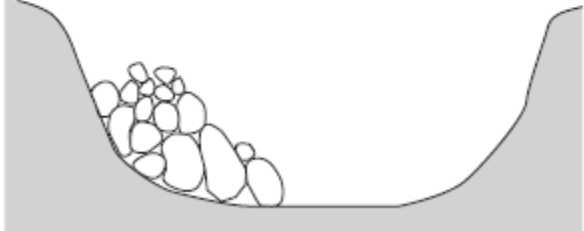


Figure 8.5 Bank-attached geomorphic units. (a) Lateral bars are formed in low-sinuosity reaches and (b) point bars on meander bends. (c) Benches are depositional features reflecting channel contraction, while (d) ledges are erosional features reflecting channel expansion. (e) Concave bank benches form in separation zones where flow impinges against bedrock on a concave bank. (a) Lerida Creek, NSW. Photograph: K. Fryirs. (b) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery. (c) Tuross River, NSW. Photograph: K. Fryirs. (d) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (e) Luangwa River, Zambia. Photograph: Gilvear *et al.* (2000).

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Table 8.3 (Continued)

Unit	Form	Process interpretation
<p>Ledge</p> 	<p>Distinctly stepped, flat-topped, elongate, bank-attached unit. Has a straight to gently curved planform, flanking the banks. Composed of the same materials as the basal floodplain (i.e. sediments are laterally continuous from the ledge to the floodplain).</p>	<p>Formed by channel expansion processes where flows selectively erode the upper units of the floodplain as the channel incises and expands. Unpaired ledges reflect lateral shift during incision, whereas paired ledges indicate incision only.</p>
<p>Boulder berm (boulder bench)</p> 	<p>Elongate, bank-attached stepped feature. Can have a convex cross-section. Comprised of coarse, boulder bedload materials with limited finer grained matrix.</p>	<p>Formed from bedload deposition in a single event under high-velocity conditions. Materials are accreted (or dumped) along the bank where flow velocity decreases substantially. Reworking is restricted to subsequent high-velocity events that have the competence to mobilise the boulders.</p>

Ledges

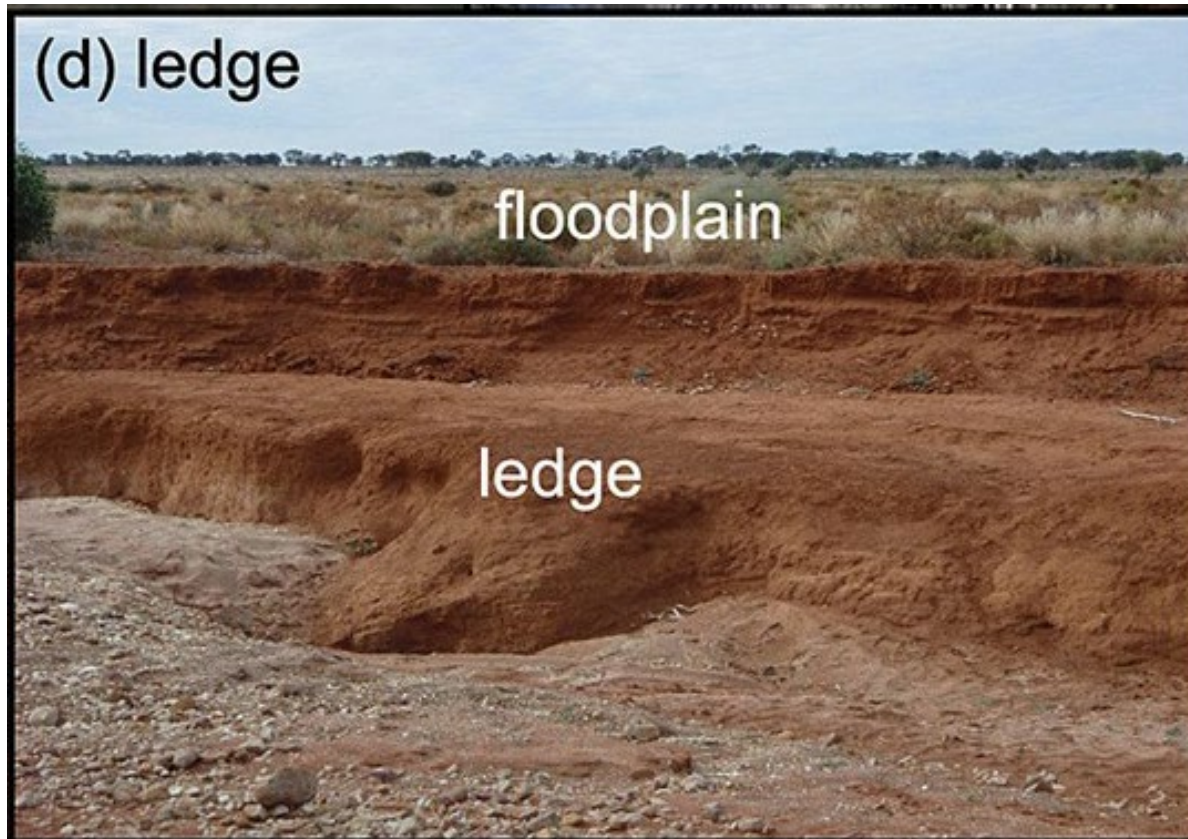
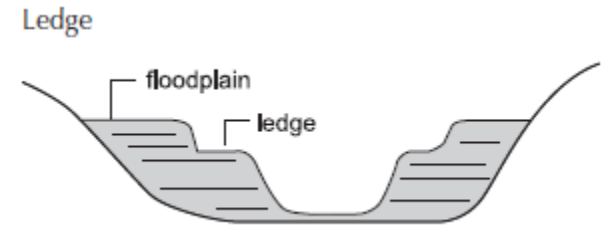
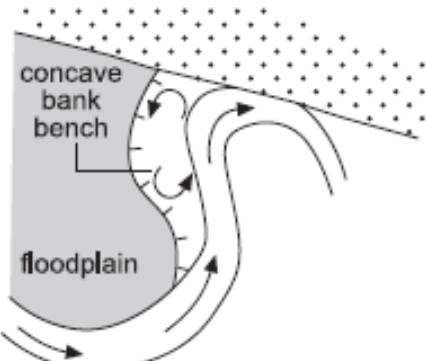


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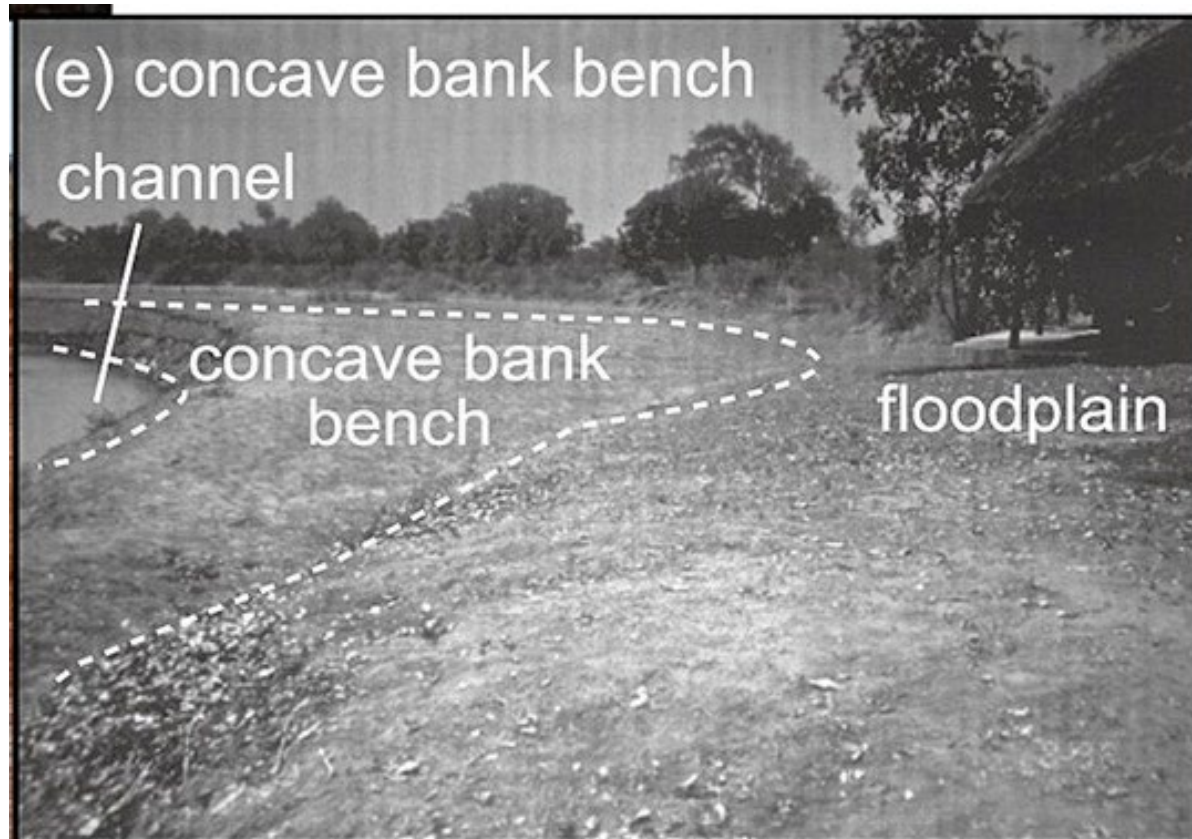
Fryirs & Brierley (2013)

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Convex Bar – on what bend?

Unit	Form	Process interpretation
<p>Concave bank bench (convex bar)</p> 	<p>Bank-attached unit, often with a low ridge across the central portion parallel to the primary channel. Located along the upstream limb (i.e. along the concave bank) of relatively tight bends that abut bedrock valley margins or a flow obstruction. Often inset against the floodplain. Comprise slackwater sediments (interbedded sands and mud) and organic materials.</p>	<p>Associated with flow separation and generation of secondary currents at high flood stage. Sedimentation occurs in sheltered backwater zones of relatively low flow velocity. Form from flow separation when the primary flow filament continues around a bend. At flood stage, flows separate from the primary filament, circulating back around the bend. This is often channelled by a shallow ridge. During the rising stages of flood events, this process may accentuate scour on the surface of the bench. Deposition of suspended-load materials subsequently occurs during waning stages.</p>

Concave Bank Bench



Concave bank bench
(convex bar)

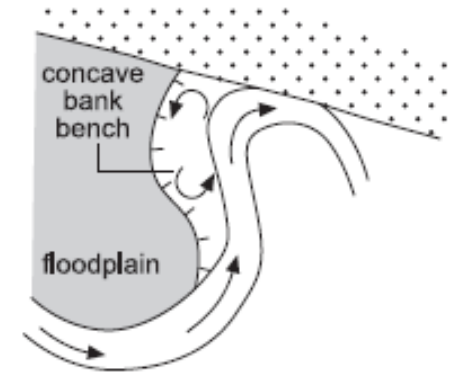


Figure 8.5 Bank-attached geomorphic units. (a) Lateral bars are formed in low-sinuosity reaches and (b) point bars on meander bends. (c) Benches are depositional features reflecting channel contraction, while (d) ledges are erosional features reflecting channel expansion. (e) Concave bank benches form in separation zones where flow impinges against bedrock on a concave bank. (a) Lerida Creek, NSW. Photograph: K. Fryirs. (b) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery. (c) Tuross River, NSW. Photograph: K. Fryirs. (d) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (e) Luangwa River, Zambia. Photograph: Gilvear *et al.* (2000).

Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Instream Geomorphic Units

- I. Intro → Geomorphic Units & Process-Form Associations
- II. Classification & Field Identification

III. Your Book (River Styles)

- I. Sculpted, Erosional Bedrock & Boulder GUs
- II. Mid-Channel, Depositional GUs
- III. Bank-Attached, Depositional GUs

IV. Sculpted, Erosional Fine-Grained GUs

- V. Unit & Compound GUs
- VI. Forced GUs

IV. Continuum of GUs

V. Fluvial Taxonomy GUs (Topographically Defined)

- I. Tier 1 – Stage
- II. Tier 2 – Shape / Form
- III. Tier 3 – Attributed

VI. GUT (Geomorphic Unit Toolkit)

Fine-Grained Sculpting

- Big events that have steep recession limbs (flashy) produce uniform deposits
- Lower flows and floods sculpt these

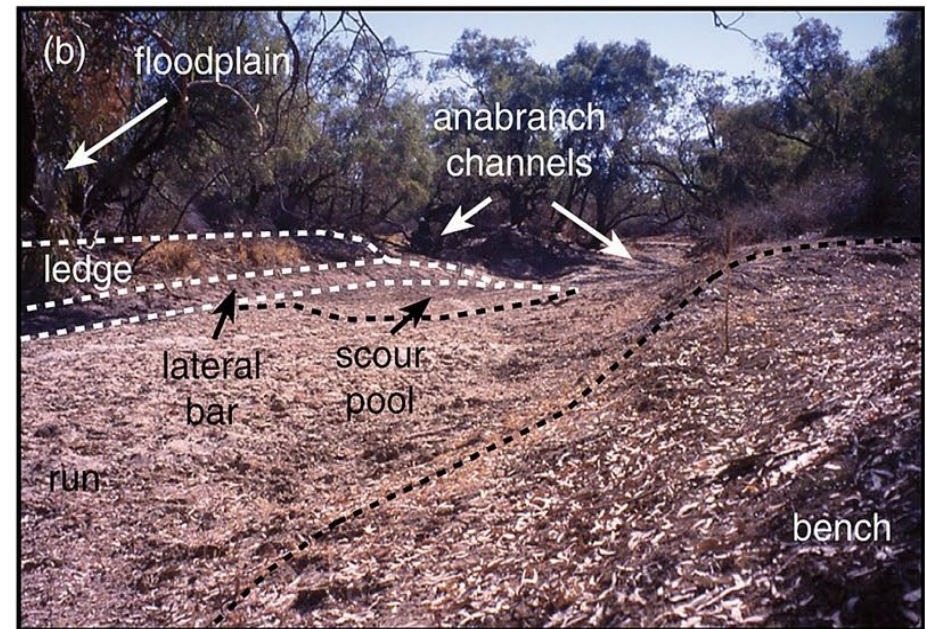
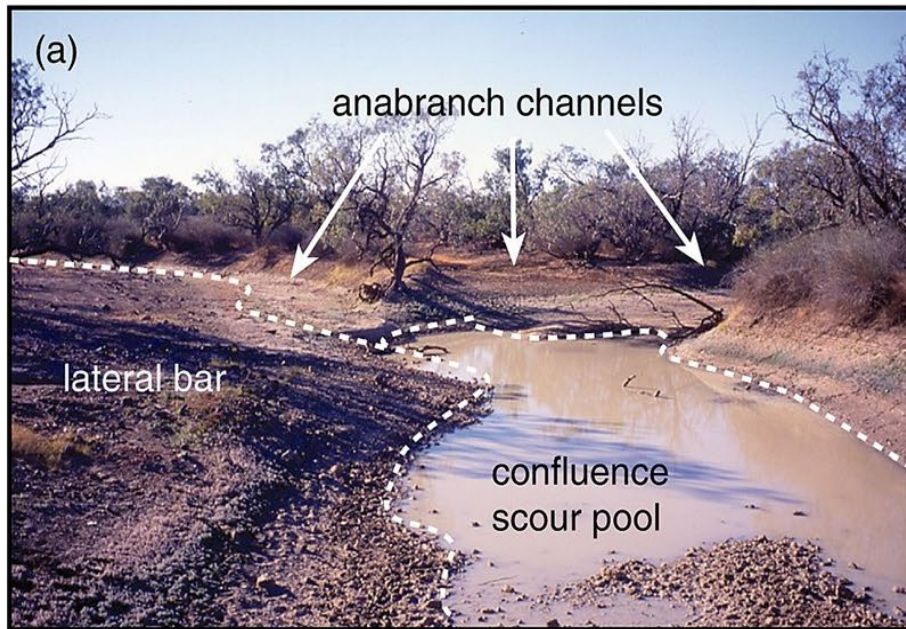


Figure 8.7 Fine-grained sculpted geomorphic units. Erosion and scour processes create forms that are similar to depositional counterparts such as bars, ledges, pools and riffles. Photographs: Cooper Creek, Central Australia. (K. Fryirs).

Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Table 8.4 Fine-grained sculpted geomorphic units

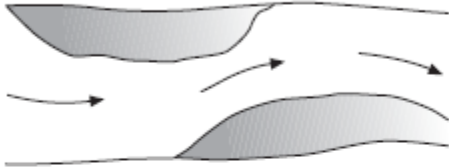
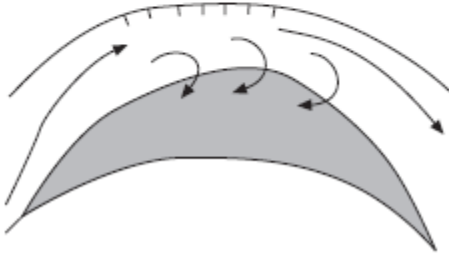
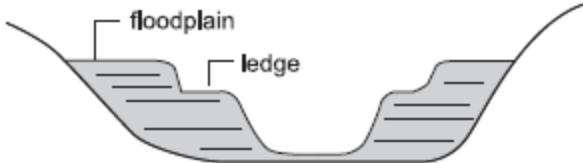
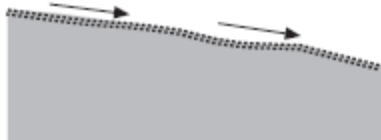
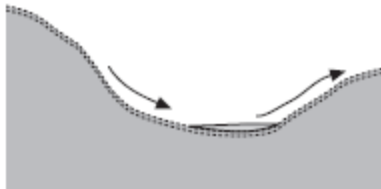
Unit	Form	Process interpretation
<p>Sculpted lateral bar</p> 	<p>Bank-attached feature that resembles a depositional lateral bar. Forms along the low-sinuosity reaches of fine-grained channels. Bar surface is inclined towards the channel but at low angles. Localised form that is not as continuous as a ledge.</p>	<p>Flow along a straight reach of river adopts a sinuous path. In fine-grained systems, these features are sculpted from the surrounding sediment of the adjacent channel bank. Sediment may subsequently be draped over the toe of the bank during waning-stage flows and smoothed by flows that inundate it.</p>
<p>Sculpted point bar</p> 	<p>Bank-attached arcuate-shaped bar that resembles a point bar along the convex banks of bends. The bar surface is typically inclined towards the channel but at a low angle.</p>	<p>These fine-grained features are sculpted from the surrounding sediment of the adjacent channel bank. Sediment is subsequently draped over the low-lying toe of the convex graded bank. May form by oblique accretion of suspended-load sediments during the waning stage of flows. Scour of adjacent pools accentuates the morphology of these features.</p>

Table 8.4 Fine-grained sculpted geomorphic units

Unit	Form	Process interpretation
<p>Ledge</p> 	<p>Distinctly stepped, elongate, flat-topped, bank-attached unit. Has a straight to gently curved planform, flanking one or both banks. Composed of the same materials as the basal floodplain (i.e. sediments are laterally continuous from the ledge to the floodplain). These erosional units reflect channel expansion.</p>	<p>Formed by bankfull flows stripping the surface layers of the bank, leaving a step adjacent to the bank. Oblique and vertical accretion may deposit small amounts of sediment atop these steps during the waning stages of flow.</p>
<p>Sculpted run</p> 	<p>Stretches of uniform and relatively featureless bed, comprising fine-grained sediment. These smooth flow zones are free-flowing areas that connect pools.</p>	<p>Plane-bed conditions promote relatively smooth conveyance of water and sediment in these linking features. Slopes are intermediate between pools and riffles.</p>
<p>Scour pool</p> 	<p>Pools may span the channel, hosting tranquil or standing flow at low stage. Alluvial pools are alternating deep areas of channel along an undulating longitudinal bed profile. Pools tend to act as sediment storage zones that occur at characteristic locations, such as the concave bank of bends in sinuous alluvial channels. In fine-grained systems they also occur in expansion zones where flows exit from more confined, laterally stable sections or where flow converges at anabranch confluences.</p>	<p>At high flow stage, when flow converges through pools, decreased roughness and greater bed shear stresses induce scour and flushing of sediment stored on the bed. Subcritical flow occurs at low flow stage, when divergent flow occurs. Pool infilling subsequently occurs, as pools act as areas of deep, low flow velocity and near-standing water conditions.</p>

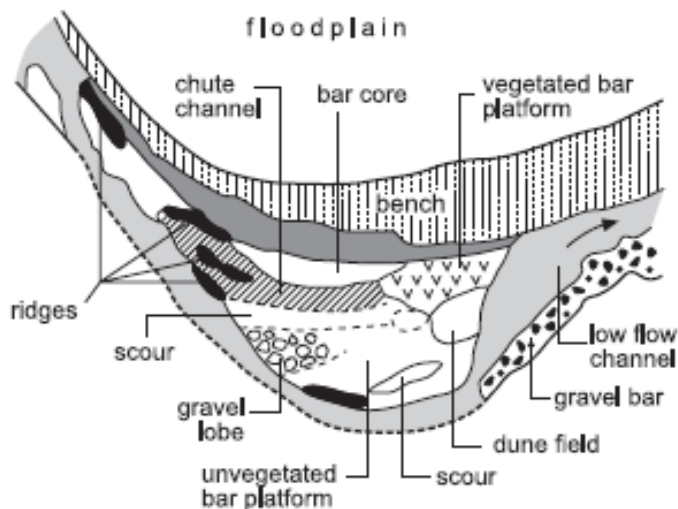
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- V. Unit & Compound GUs**
- VI. Forced GUs
- IV. Continuum of GUs
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 - II. Tier 2 – Shape / Form
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Compound

formed in low-energy, fine-grained settings. **Unit features** are **products of single depositional events**, whereas **compound features** reflect a range of flow conditions and **reworking events**. Inevitably, the pattern of features is

Compound bank-attached bar



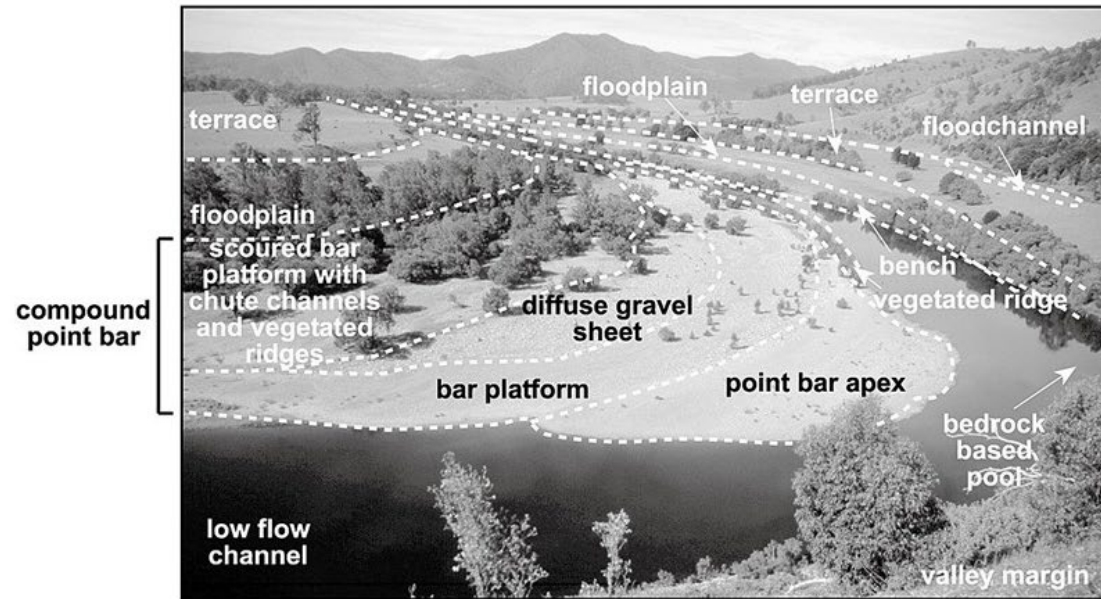
Bank-attached bar that is comprised of an array of smaller scale geomorphic units. Generally composed of laterally accreted sand or gravel, but may include silt or boulders. Variable morphology reflects material texture, flow energy and the history of flood events that form and rework the bar. If a bar is reworked by chute channels, ramps or dissection features may form. Deposition may create ridges and lobes. If vegetation colonises parts of the bar, additional depositional features result. Forms of bank-attached compound bar include compound point bars and compound lateral bars.

Development of compound lateral or point bar forms is dependent on channel alignment (and associated implications for the distribution of flow energy over the bar surface at different flow stages) and associated patterns of reworking by flood events. Formed initially from the lag deposition of coarser sediments (a unit bar). At high flow stage the bar may be reworked or material deposited around obstructions. At low flow stage the bar may have finer depositional features deposited on top of the bar platform, or a range of bedforms preserved, reflecting sediment transport across the bar surface.

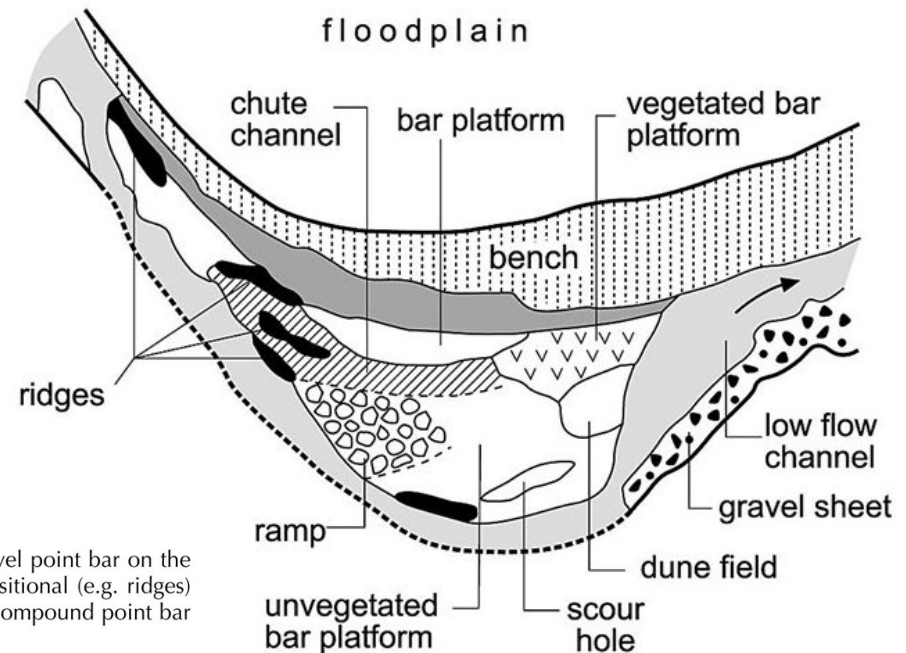
Compound Bars...

- Umm... well, same things and some other things keeps happening
- Multiple units...

(a) oblique photograph of a compound point bar



(b) planform view of a compound point bar



Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Figure 8.8 The structure of compound point bars. (a) An oblique view of a compound gravel point bar on the Manning River, NSW, Australia. Geomorphic units that make up this compound bar are depositional (e.g. ridges) and erosional (e.g. chute channels). Photograph: G. Brierley. (b) A planform view of a typical compound point bar showing the juxtaposition of a range of geomorphic units.

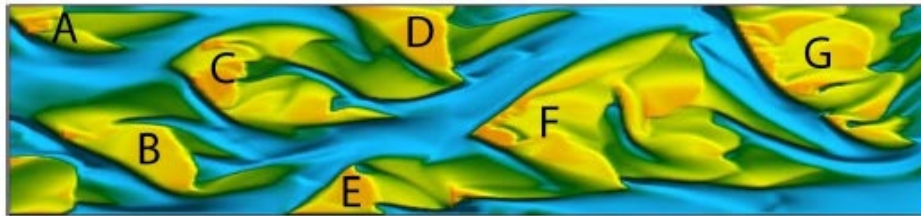
In dynamic systems almost everything is compound...

Schuurman (2015)

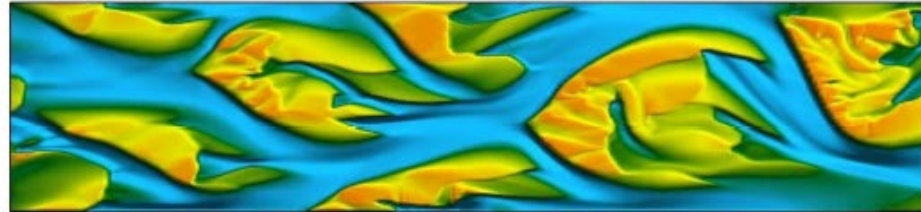
DOI: [10.13140/RG.2.1.3582.3529](https://doi.org/10.13140/RG.2.1.3582.3529)

a. Bed level

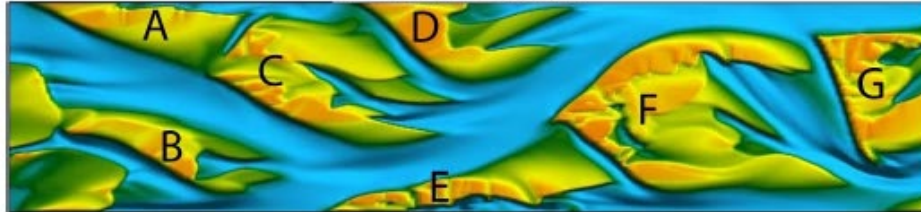
Timestep:12 months



Timestep:14 months



Timestep:16 months

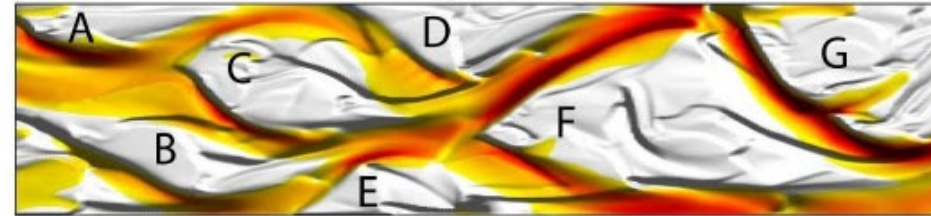


x-coordinate (km)

-5 0 5 10m

b. Sediment transport rate

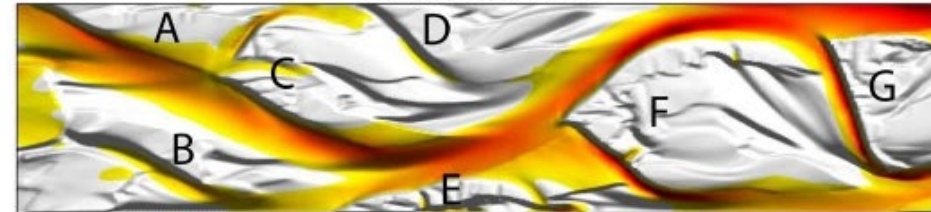
Timestep:12 months



Timestep:14 months



Timestep:16 months

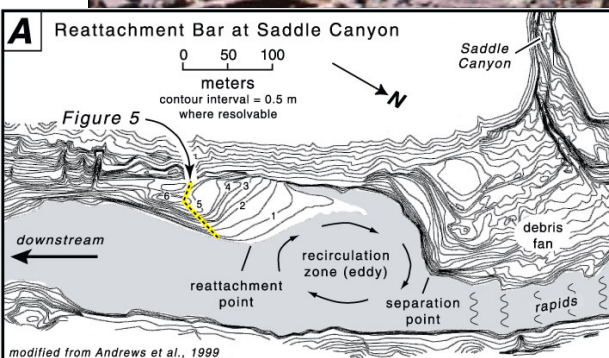
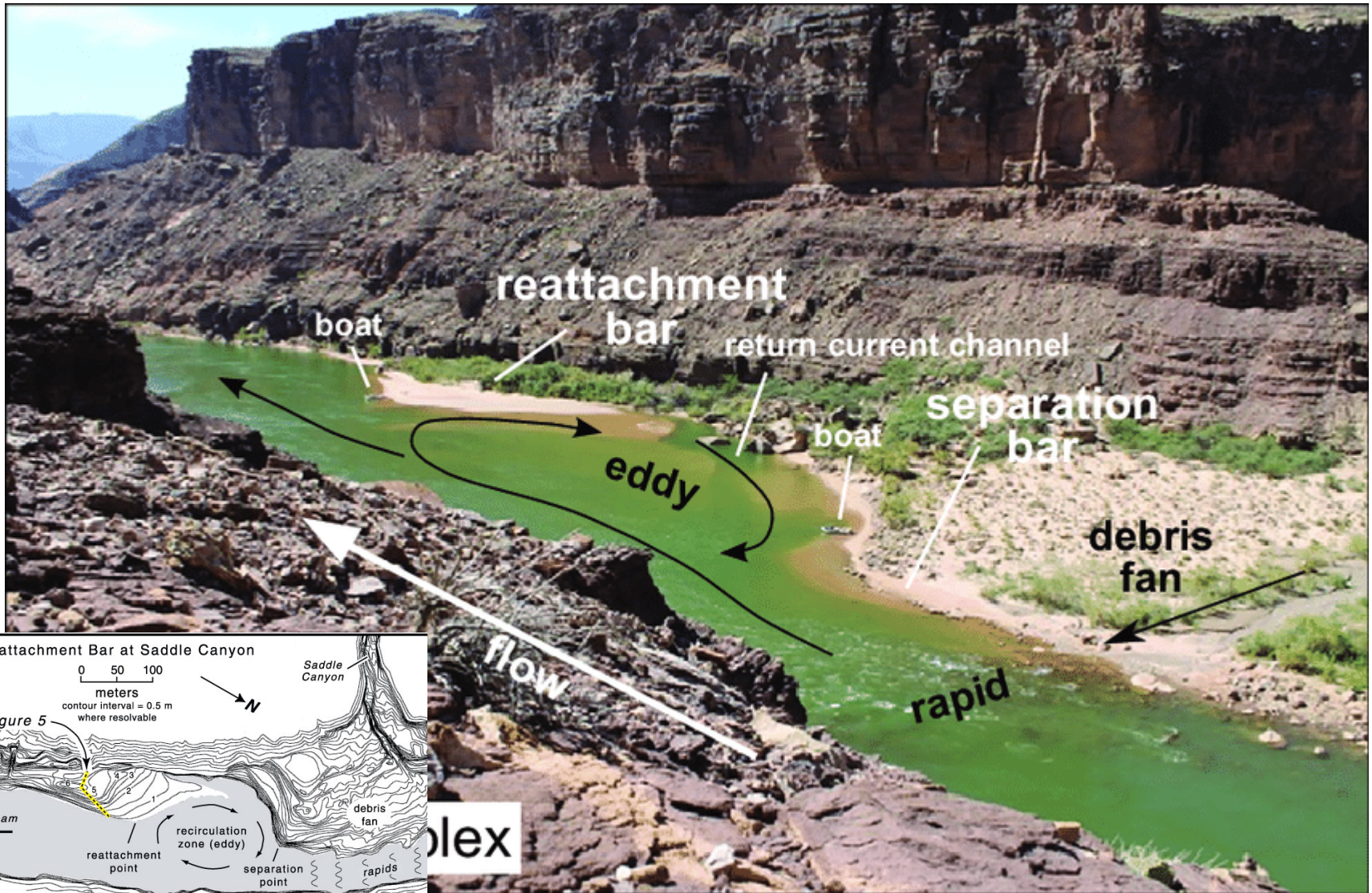
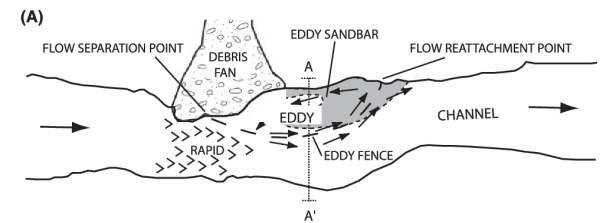


x-coordinate (km)

0 0.005 0.01 m²/s

Figure 3.5: Evolution of two bifurcations upstream of bars C and F in Run 2. The branch between bars A and C closed due to downstream expansion of bar A. This way, bar C becomes a bank-attached bar. At the same time, the bifurcation of bar F becomes more asymmetrical. This could be due to a change in bifurcation angle and flow direction of the channel in the north of bar E.

Fan-Eddy Complex



How horrendous it can get...

Six potential phases of diagonal bar evolution

NON-DIAGONAL BAR PHASES

DIAGONAL BAR PHASES

Chute begins to Form on Inner Margin

Compound Point Bar

I Bank-Attached Point Bar Forms

Chute begins to form on inner margin

II Partially Bank-Attached Diagonal Bar

Vegetation Colonization & Surface Elevation > BF

Floodplain

Chute Cutoff takes place completely disconnecting bar from inner margin

II Diagonal Bar with Chute on Inner Margin

Compound Diagonal Bar

New Phase 1 Bar forms along Diagonal Bar

Floodplain Island

Overflow chutes dissect diagonal bar

IV Diagonal Bar with Dissecting Chutes

Compound Diagonal Bar

Floodplain Island

Outer anabranch aggrades or inner chute cutoff degrades to point that flow is more symmetric to both.

V Diagonal Bar with Equal Anabranches

Compound Diagonal Bar

Floodplain Island

Inner chute cutoff becomes primary anabranch, and outer anabranch is now higher. Diagonal flow switches direction from 'inner to outer' to 'outer to inner'

VI Mature Diagonal Bar w/ Anabranch Swap

Compound Diagonal Bar

Floodplain & Relic Channel

AVULSION followed by Vegetation Colonization & Surface Elevation > BF



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VI. Forced GUs

IV. Continuum of GUs

V. Fluvial Taxonomy GUs (Topographically Defined)

I. Tier 1 – Stage

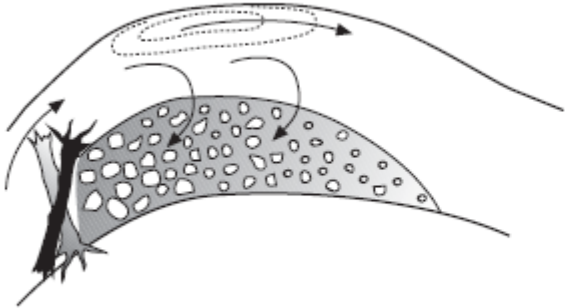
II. Tier 2 – Shape / Form

III. Tier 3 – Attributed

VI. GUT (Geomorphic Unit Toolkit)

Structurally-Forced

Forced bank-attached bar



Bank-attached bar that is induced by a flow obstruction (e.g. bedrock outcrop, boulders, large wood, vegetation). The resultant bar form often has a downstream fining sediment sequence.

Perturbations in flow and subsequent deposition are induced by obstructions. The resultant bar morphology is shaped by the flow obstruction, which promotes turbulence and deposition in its wake via secondary flow structures. Depending on flow stage, secondary flow structures may induce local scour around the obstruction.

^aModified from Brierley and Fryirs (2005). © Wiley–Blackwell Publishing. Reproduced with permission.



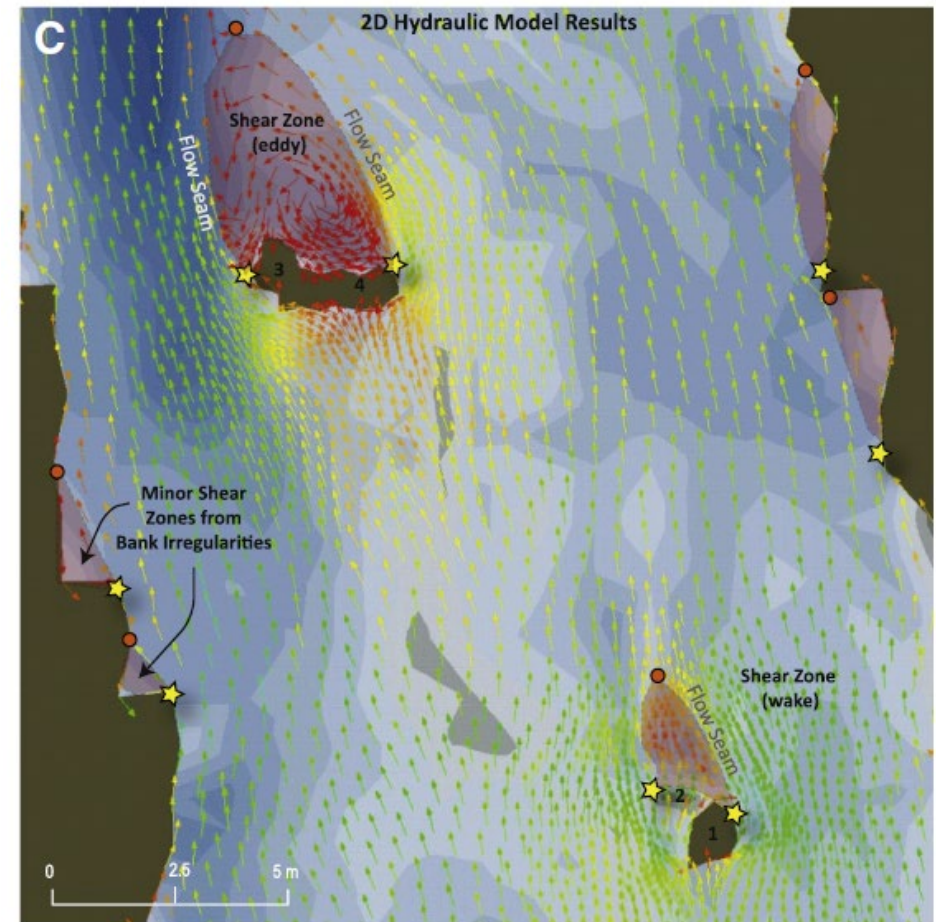
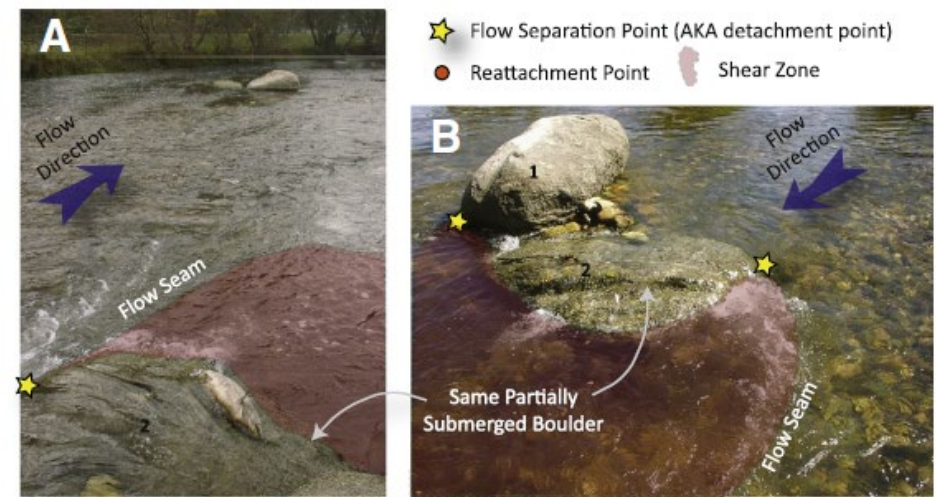
WOOD ACCUMULATION on a
Post-Assisted Log Structure (PALS)



BEAVER DAM ACTIVITY on a
beaver dam analogue (BDA)

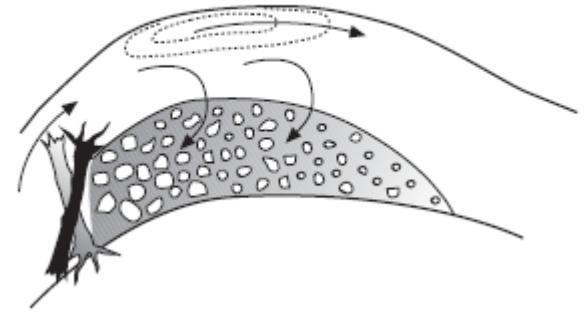
Recall these terms..

- A **structural element** is a discrete object that directly influences hydraulics
- Structural elements produce:
 - Flow separation points
 - Flow seams
 - Shear zones
 - Reattachment point or zone
- Help predict zones of erosion, deposition, margins and 'forced' geomorphic units



From: Wheaton et al. (2015) – Geomorphology;
DOI: [10.1016/j.geomorph.2015.07.010](https://doi.org/10.1016/j.geomorph.2015.07.010)

Forced Bank-Attached Bar



(d) forced bank-attached bar

Figure 8.6 Other types of bank-attached geomorphic units. (a) Bars may occur at tributary confluences, or as (b) berms and (c) point dunes. (d) Forced bars occur where obstructions such as wood or vegetation lead to deposition against the channel bank. (a) Tongariro River, New Zealand. Photograph: P. Chappell. (b) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (c) Kangaroo River, NSW. Photograph: K. Fryirs. (d) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery.

Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

Point Dunes

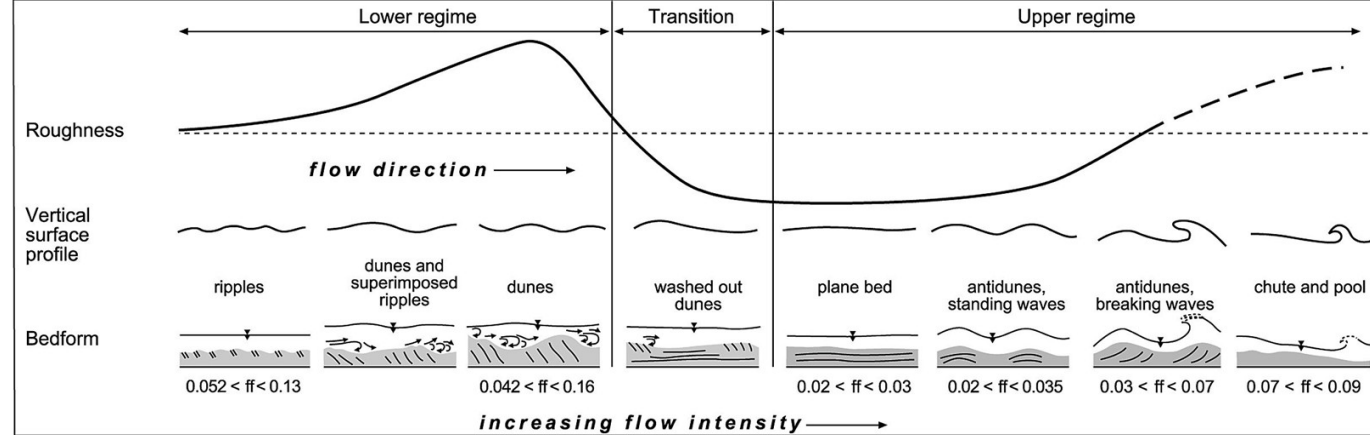
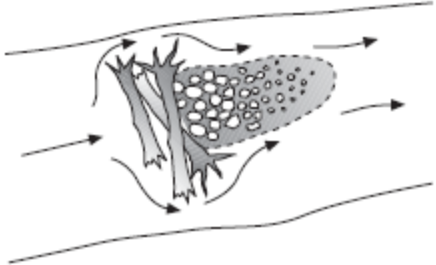
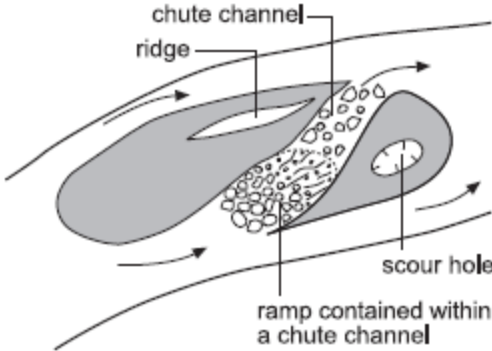


Figure 8.6 Other types of bank-attached geomorphic units. (a) Bars may occur at tributary confluences, or as (b) berms and (c) point dunes. (d) Forced bars occur where obstructions such as wood or vegetation lead to deposition against the channel bank. (a) Tongariro River, New Zealand. Photograph: P. Chappell. (b) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (c) Kangaroo River, NSW. Photograph: K. Fryirs. (d) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery.

Table 8.2 (Continued)

Unit	Form	Process interpretation
<p>Forced mid-channel bar (pendant bar, wake bar, lee bar)</p> 	<p>A mid-channel bar form that is induced by a flow obstruction (e.g. bedrock outcrop, boulders, large wood, vegetation). The resultant bar form often has a downstream-dipping slip face as the bar extends downstream.</p>	<p>Perturbations in flow and subsequent deposition are induced by obstructions. The resultant bar morphology is shaped by the flow obstruction, which forces flow around the obstruction and deposition in its wake in secondary flow structures. Depending on flow stage, these secondary flow structures may locally scour the bed. These bars build in a downstream direction and may become vegetated.</p>
<p>Compound mid-channel bar</p> 	<p>A mid-channel bar that comprises an array of smaller scale geomorphic units. Variable morphology reflects material texture, flow energy and the history of flood events that induce formation and subsequent reworking, producing chute channels, ramps or dissection features. Further deposition may form ridges and lobes. If vegetation colonises parts of the bar, additional depositional features result, producing an island.</p>	<p>The assemblage of geomorphic units is dependent largely on channel alignment (and associated distribution of flow energy over the bar surface at different flow stages) and patterns of reworking by flood events. Formed initially from the lag deposition of coarser sediments (a unit bar). At high flow stage the bar may be reworked or material may be deposited around obstructions. At low flow stage the bar may have finer depositional features deposited on top of the bar platform. The range of bedforms reflects sediment transport across the surface.</p>

^aModified from Brierley and Fryirs (2005). © Wiley–Blackwell Publishing. Reproduced with permission.

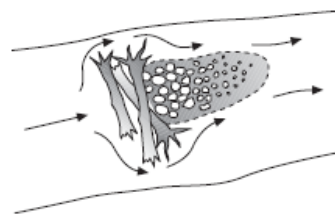
Forced Mid-Channel Bar

- By a tree?



Figure 8.4 Other types of mid-channel geomorphic units. (a) Islands are vegetated bars, (b) bedrock core bars/islands occur where vegetation grows on finer substrates deposited on bedrock outcrops and (c) forced bars occur where obstructions such as wood or vegetation induce deposition in the middle of the channel bed. (a) Roger W. Ruess, Institute of Arctic Biology, University of Alaska; www.iab.uaf.edu/research/research_project_by_id.php?project_id=171. (b) Kruger National Park, South Africa. Photograph: G. Brierley, (c) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs.

Forced mid-channel bar
(pendant bar, wake bar, lee bar)



A mid-channel bar form that is induced by a flow obstruction (e.g. bedrock outcrop, boulders, large wood, vegetation). The resultant bar form often has a downstream-dipping slip face as the bar extends downstream.

Perturbations in flow and subsequent deposition are induced by obstructions. The resultant bar morphology is shaped by the flow obstruction, which forces flow around the obstruction and deposition in its wake in secondary flow structures. Depending on flow stage, these secondary flow structures may locally scour the bed. These bars build in a downstream direction and may become vegetated.

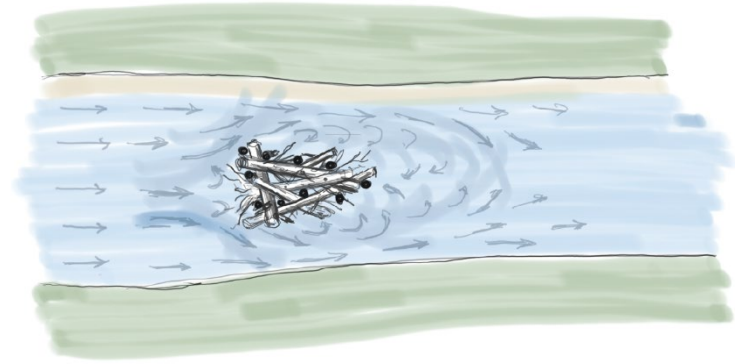
Fryirs & Brierley (2013)

DOI: [10.1002/9781118305454](https://doi.org/10.1002/9781118305454)

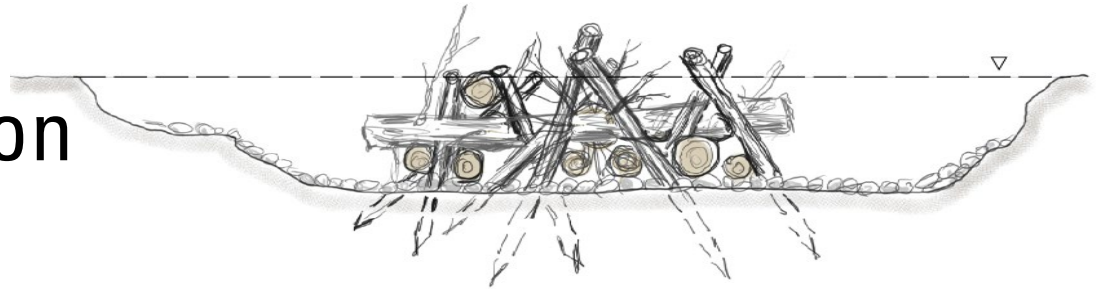
Mid-channel PALS

By a jam?

Planform



Cross-section



Profile

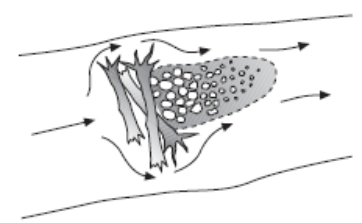


Adapted from Figure 4.25 of Appendix D of Shahverdian et al. (2019)
– Chapter 4 LTPBR Manual DOI: [10.13140/RG.2.2.22526.64324](https://doi.org/10.13140/RG.2.2.22526.64324)

Flow 

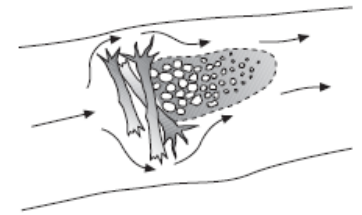
Structurally Forced Mid-Channel Bar

Forced mid-channel bar
(pendant bar, wake bar, lee bar)



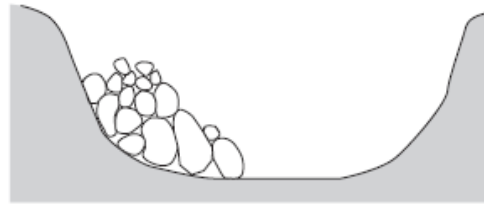
Structurally Forced Mid-Channel Bar

Forced mid-channel bar
(pendant bar, wake bar, lee bar)



Boulder Berm

Boulder berm
(boulder bench)



Elongate, bank-attached stepped feature. Can have a convex cross-section. Comprised of coarse, boulder bedload materials with limited finer grained matrix.

Formed from bedload deposition in a single event under high-velocity conditions. Materials are accreted (or dumped) along the bank where flow velocity decreases substantially. Reworking is restricted to subsequent high-velocity events that have the competence to mobilise the boulders.



- Explained by structural-forcing wake or eddy
- & Very high competence

Figure 8.6 Other types of bank-attached geomorphic units. (a) Bars may occur at tributary confluences, or as (b) berms and (c) point dunes. (d) Forced bars occur where obstructions such as wood or vegetation lead to deposition against the channel bank. (a) Tongariro River, New Zealand. Photograph: P. Chappell. (b) Faulkenhagen Creek, western NSW. Photograph: K. Fryirs. (c) Kangaroo River, NSW. Photograph: K. Fryirs. (d) Washington, USA. Photograph: Dave Montgomery from www.uvm.edu/~geomorph/gallery.

Fryirs & Brierley (2013)

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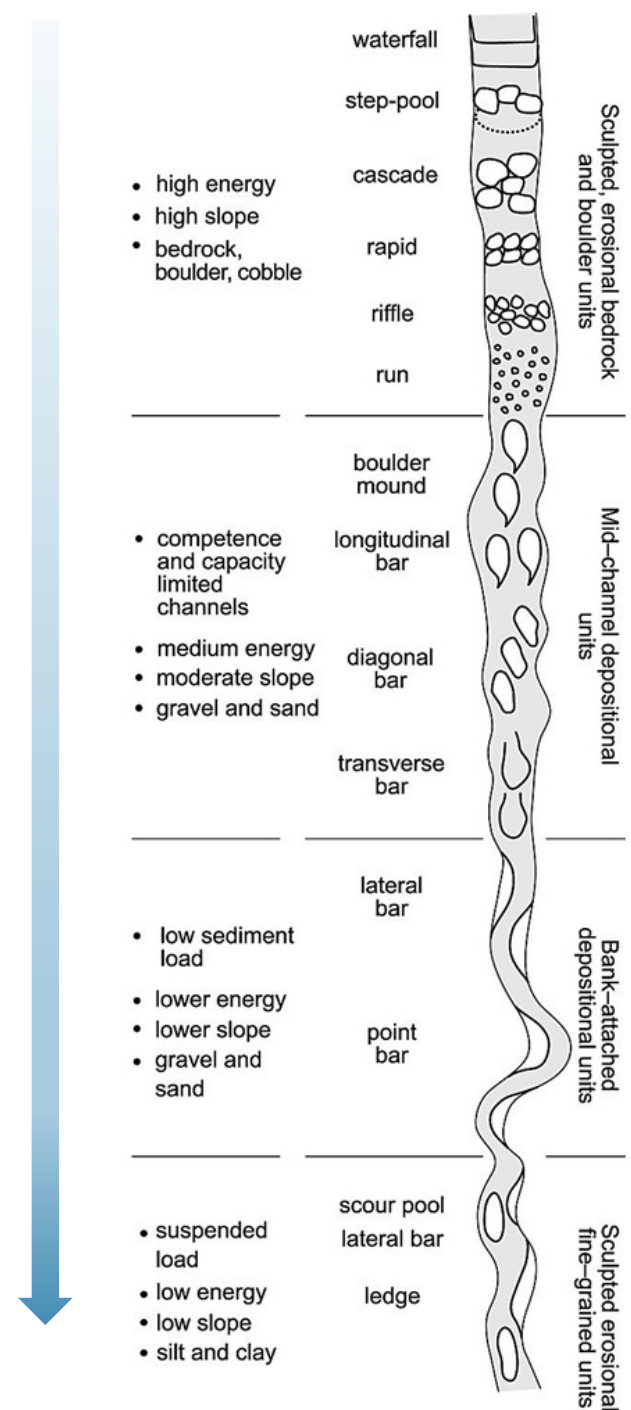
Hypothetical Longitudinal Continuum of Instream GUs

- If you buy the individual form-process linkages for each GU, you can start to predict the types of riverscapes in which different units will be present / dominate

Figure 8.9 The longitudinal continuum of instream geomorphic units. Transition from sculpted, erosion bedrock and boulder forms in high-slope, high-energy conditions, to mid-channel, bank-attached and sculpted fine-grained units in lower slope, lower energy conditions is shown. This continuum does not occur along all rivers. Rather, it reflects local slope, grain size, sediment supply conditions and the presence of forcing features.

Fryirs & Brierley (2013)

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Geomorphic Units Related to Sediment Supply and Transport Capacity

- Transport capacity and sediment supply can also be used to predict presence of units

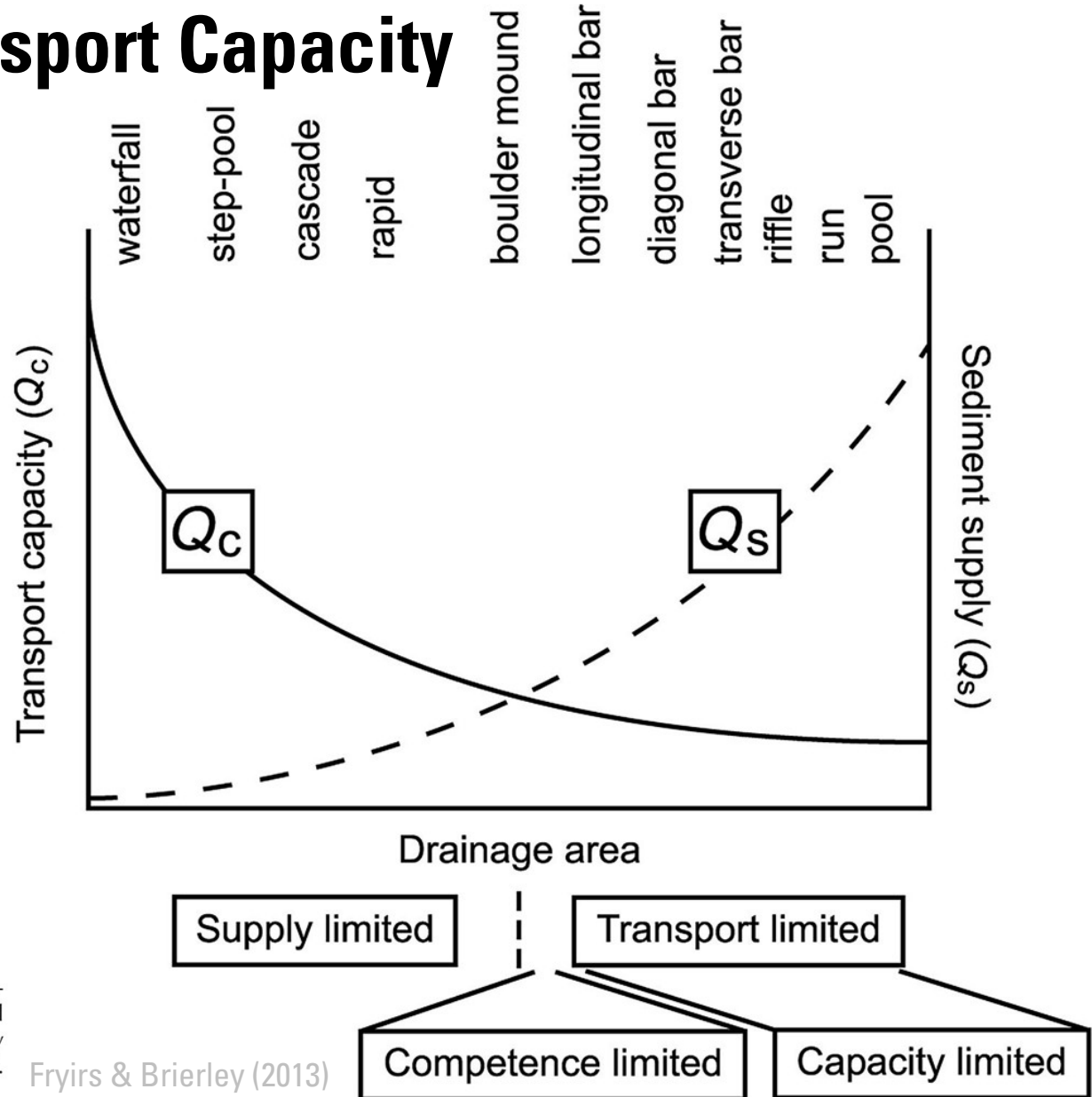


Figure 8.10 Sediment supply and transport capacity relationships for sculpted, erosional and mid-channel instream geomorphic units. Modified from Montgomery and Buffington (1997). © Geological Society of America. Reproduced with permission.

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